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MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

VOLUME XV

CONTAINING PAPERS SUBMITTED AT THE ANNUAL MEETING IN 1931

(This volume contains papers in Botany, Forestry and Zoölogy only. Volume XVI will contain papers in Anthropology, Geography, Geology and Mineralogy, History and Political Science, Language and Literature, Psychology, and Sanitary and Medical Science.)

PAPERS

OF THE

MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

EDITORS
EUGENE S. McCARTNEY
UNIVERSITY OF MICHIGAN
PETER OKKELBERG
UNIVERSITY OF MICHIGAN

VOLUME XV

"Pusilla res mundus est nisi in illo
quod quaerat omnis mundus habeat."
— Seneca, *Naturales Quaestiones*

Ann Arbor
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1932

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CONTENTS

BOTANY

PAGE

PRELIMINARY REPORT ON MICHIGAN ALGAE, EXCLUSIVE OF DESMIDS AND DIATOMS. Alma B. Ackley 1

MICROFOSSILS FROM GREENLAND COAL. Chester A. Arnold 51

A THERMOPHILIC CALOTHRIX IN MICHIGAN. Lloyd C. Cochran.. 63

PLANT VAGRANTS IN AMERICA. Melvin R. Gilmore 65

A POLYPLOID EGGPLANT, *SOLANUM MELOGENA* L. Edavaleth K. Janaki-Ammal 81

CHROMOSOME CONFIGURATIONS DURING THE HETEROTYPIC PROPHASE AND METAPHASE IN CERTAIN OENOTHERAE AND THEIR GENETIC SIGNIFICANCE. Chandrakant G. Kulkarni 83

THE COMPARATIVE MORPHOLOGY OF GERMINATING ASCOSPORES IN CERTAIN SPECIES OF THE HYSTERIACEAE. Marion L. Lohman 97

THE DESMIDS OF MICHIGAN, WITH PARTICULAR REFERENCE TO THE DOUGLAS LAKE REGION. George E. Nichols and Alma B. Ackley.. 113

DISTRIBUTION OF THE GENUS POTAMOGETON IN MICHIGAN. Henry J. Oosting.. 141

SEED DEVELOPMENT IN *AMARANTHUS CAUDATUS* L. Edward F. Woodcock.. 173

THE PENETRATING POWER OF THE RHIZOME OF QUACK GRASS *AGROPYRON REPENS* (L.) BEAUV. Edward F. Woodcock.... 179

FORESTRY

NOMENCLATURE IN THE LITERATURE OF FOREST FIRE CONTROL. Shirley W. Allen 183

SOME RESUPINATE POLYPORES FROM THE REGION OF THE GREAT LAKES. III. Dow V. Baxter............................ 191

SAMPLING FOREST TYPES: SUGGESTIONS BASED ON THE MICHIGAN LAND ECONOMIC SURVEY. Joseph Kittredge, Jr., and George T. Olson 229

THEORY AND PRACTICE OF FOREST TYPING, WITH SPECIAL RELATION TO THE HARDWOOD AND HEMLOCK ASSOCIATIONS OF NORTHERN MICHIGAN. George S. McIntire................ 239

PAGE
A SHORT METHOD OF ESTIMATING POSSIBILITIES OF SUSTAINED YIELD IN FOREST PRODUCTION. Donald M. Matthews...... 253
FUR BEARERS IN MICHIGAN'S FOREST AREAS. Harry D. Ruhl .. 261
SOIL MAPS AS A BASIS FOR MAPPING ORIGINAL FOREST COVER. Jethro Otto Veatch.................................... 267
STEM FORM OF WHITE OAK. Robert Kirby Winters............ 275
RESULTS OF THINNING IN WHITE PINE. Leigh J. Young 337

ZOÖLOGY

NOTES AND STUDIES ON ARACHNIDA. II. ARANEAE FROM THE DOUGLAS LAKE REGION, MICHIGAN. I. Arthur M. Chickering 349
SPERMATOGENESIS IN THE BELOSTOMATIDAE. III. THE CHROMOSOMES IN THE MALE GERM CELLS OF A LETHOCERUS FROM NEW ORLEANS, LOUISIANA. Arthur M. Chickering......... 357
LIMNETIC DISTRIBUTION AND MIGRATION OF CORETHRA LARVAE IN TWO MICHIGAN LAKES. Frank E. Eggleton 361
THE HERPETOLOGICAL FAUNA OF THE PIGEON LAKE REGION, MIAMI COUNTY, KANSAS. Howard K. Gloyd 389
OBSERVATIONS ON THE BREEDING BEHAVIOR AND HABITATS OF FISHES IN SOUTHERN MICHIGAN. Thomas L. Hankinson.... 411
EXPERIMENTAL VERIFICATION OF NATURAL HYBRIDIZATION BETWEEN DISTINCT GENERA OF SUNFISHES. Carl L. and Laura C. Hubbs.. 427
TAXONOMY AND DISTRIBUTION OF THE FRESH-WATER SPONGES (SPONGILLIDAE) OF MICHIGAN. Marcus C. Old............. 439
NOTES ON THE OCCURRENCE OF SIX OF THE LESS COMMON SPECIES OF THE FAMILY FRINGILLIDAE, CLASS AVES, IN SOUTHERN MICHIGAN. Richard E. Olsen 479
FALL MIGRATION OF THE BLACK DUCK FROM NORTHERN MICHIGAN. Miles D. Pirnie 485
LIMNOLOGICAL INVESTIGATIONS ON NORTHERN MICHIGAN LAKES. II. A FURTHER STUDY OF DEPRESSION INDIVIDUALITY IN DOUGLAS LAKE. Paul S. Welch and Frank E. Eggleton 491

ILLUSTRATIONS

PLATES

PLATE FACING PAGE
I–III. Subbituminous coal from Greenland, showing luster, irregular fracture, tendency to cubic fracture, parallel checking, banding and a large spore 60
IV. Figures showing spores, probable bryophytic antheridia and pollen grains, and some other objects which were found in Greenland coal 60
V. Electric-light bulb, showing algal growth (*Calothrix thermalis*) on surface 64
VI. Algae (*Calothrix thermalis*) found growing in a water bath 64
VII–VIII. Triploid and diploid eggplants 81
IX–X. Chromosome configurations in Oenotherae 95
XI–XII. Germinating ascospores of Hysteriaceae 112
XIII–XIV. Seed of *Amaranthus caudatus* L. 178
XV. Fig. 1. Juglans root, with imbedded quack-grass rhizome 182
Fig. 2. One-year-old seedling of Juglans, penetrated by rhizome of quack grass
XVI. Drawings showing penetrating power of quack-grass rhizome 182
XVII–XXVI. Species of Poria 228
XXVII. Stand of white oak near Wardensville, West Virginia 288
XXVIII. Mixed stand of black and chestnut oak near Wardensville, West Virginia 288
XXIX. Spermatogonia, spermatocytes and spermatids of Lethocerus 360
XXX–XXXII. Pigeon Lake, Kansas, showing shores, marshes and the low bluff on the north shore 409
XXXIII. Saline River, showing breeding habitats of fishes 424
XXXIV. Fig. 1. Deep pool in Saline River, where fish deposit eggs on bottoms of stones 424
Fig. 2. Eggs of the fan-tail darter, similar to those found in Saline River
XXXV–XXXVII. Spicules of fresh-water sponges of Michigan 477

FIGURES IN THE TEXT

FIGURE PAGE
1. Ascopores of four species of Glonium 104
2. Stages of germ-tube development in four species of Glonium 105
3–4. Diagrams illustrating the proportionate distribution of age classes of trees for rotations of 160 and 120 years 257–258
5. A tree stem of form class 0.70 containing a theoretical girder of equal length 281
6. Curve of equation for measuring stem form of white oak 283
7*a–c*. Stem curves of white oak 292–293
8. Comparison of empirical curves of white oak and theoretical curves of Behre's formula 301
9. Root-swell of white oak trees as shown by diameter-height curves 313
10. Chart showing relation between relative crown length and genuine form quotient of trees 320
11. Graphic representation of the equation $y^2 = px^r$ 324
12. Graphic representation of Heijbel's equation 331
13–16. Size-frequency curves of body length of Corethra larvae from Third Sister Lake profundal benthic zone..... 375
17. Size-frequency curve of body length of Corethra larvae from profundal benthic zone within the six major depressions of Douglas Lake 376
18. Size-frequency curves of body length of Corethra larvae from the limnetic zone within the six major depressions of Douglas Lake 378

MAPS

MAP PAGE
1. Nugsuaks Peninsula and Disko Island, west coast of Greenland 52
2. Map of Michigan, showing limits of forest species and types in relation to the transitional belt of soils..... 272
3. Pigeon Lake, Kansas 390
4–8. Distribution of records of species of fresh-water sponges in Michigan 455, 457, 459, 461, 463
9. Distribution of less common sparrows in central counties of southern Michigan 480
10. Spot map showing locations at which 194 banded black ducks were reported shot 487

PRELIMINARY REPORT ON MICHIGAN ALGAE, EXCLUSIVE OF DESMIDS AND DIATOMS *

ALMA B. ACKLEY

THE following list of Michigan algae is based primarily upon identifications made during an eight-year survey of the algae of the state. This study was begun in 1922 at the Michigan Biological Station on Douglas Lake under the direction of Dr. George E. Nichols of Yale University and completed under the supervision of Dr. L. H. Tiffany and Dr. E. N. Transeau of The Ohio State University. I am greatly indebted to each of these men for valuable suggestions in field work, assistance in taxonomic determinations and the loan of literature and unpublished manuscripts.

Previous to the present survey, little was known of the taxonomy or distribution of Michigan algae. Wood (1874) published a list of algae from North America which contained five species from Michigan. Campbell (1886) presented a list of plants that he collected on Grosse Isle, near the mouth of the Detroit River. This list is especially rich in desmids. Johnson (1894–95) reported a number of desmids, many of which were collected in the region of Ann Arbor, and W. and G. S. West (1898) published a list of desmids from the United States based chiefly upon collections and notes left by Professor L. N. Johnson at the time of his death. Collins (1909) mentions a few species from Michigan in his study of the green algae of North America. There are but two recent papers

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* Paper from the Department of Botany, The Ohio State University, No. 272; a report of part of the taxonomic section of a thesis presented to the Graduate School of The Ohio State University for the degree of Doctor of Philosophy on August 29, 1930; contribution from the Department of Botany, The College of the City of Detroit and the University of Michigan Biological Station.

dealing exclusively with Michigan algae. Transeau (1917) published a list of 226 species and varieties of algae, most of which were collected during the summer of 1915. In addition to the list of species, the author has indicated the date and location of the collection, as well as the nature of the habitat. Tiffany (1926) listed 57 species of algae from the digestive tract of a gizzard shad taken from the Raisin River in Monroe County.

Most of the species listed in these works have been found in the present survey, but those that have not, have been included in this report, thus making the list complete for all of the known or reported species and varieties of these groups.

During the period of this survey all the counties of the Northern Peninsula have been visited and most of those in the Southern Peninsula. Intensive collecting has been done in the regions of Douglas Lake, Ann Arbor, Lansing and Detroit. These collections have been supplemented by others from Dr. G. E. Nichols for the Douglas Lake region, the late Dr. J. Metzelaar of the Conservation Department, and Professor T. L. Hankinson of Michigan State Normal College. In all, over 1,700 lots of material have been examined.

LABORATORY AND FIELD METHODS

The survey of as large a territory as Michigan did not permit a detailed investigation of all of the ecological factors involved. Therefore, only the two specific factors of temperature and hydrogen-ion concentration were investigated in detail. The usual colorometric method with La Motte indicators and color standards was used for the hydrogen-ion determination. These factors will be considered in detail in the final report.

In the field, the algal collections were placed in previously numbered vials and notes were taken on date, location, habitat, relative abundance, so far as it could be determined in the field, and the general appearance of the growth. Hydrogen-ion concentration and temperature were recorded for a large majority of the collections. Whenever possible, a microscope was carried and field determinations were made for the motile forms. Transeau's preservative, consisting of six parts of water, three parts of 95 per cent alcohol, and one part of formalin, was added at once and the determinations of species were completed in the laboratory.

The collecting of desmids and other small forms was greatly facilitated by the use of a wire flour sieve below which a very fine linen or silk cloth was suspended. Water was dipped from the small pools or places having an abundance of vegetation, by means of an inverted bottle, and poured through the sieve. The filamentous forms and sticks remained in the sieve and the small forms could be concentrated in the cloth below. The "richness" of the collection was determined by placing a small amount in a thin test tube and examining with a 12 × pocket lens. A pocket lens was also used in selecting spore-producing stages of the filamentous algae. This was very helpful in those genera in which determinations of species depended upon mature spores or in which several forms were growing in close proximity.

In the laboratory, lists of species were made for each bottle and numbered to correspond with the field notes. Permanent microscopic slides were made for all species determined after 1923, and the material from which these determinations were made is in the herbarium of the author. Records were kept of all variations from the original descriptions and drawings made for the rare or unusual forms. These descriptions and figures will appear in the final report of the survey.

LIST OF SPECIES

The following list includes all of the algae (exclusive of the desmids and diatoms) thus far known to occur or reported as occurring in Michigan. The nature of the habitat, together with the relative abundance for the places indicated, date of collection, distribution by counties and records of previous workers, is given for each species.

MYXOPHYCEAE

CHROOCOCCALES

CHROOCOCCACEAE

APHANOCAPSA DELICATISSIMA W. & G. S. West. — Small lakes; locally abundant; May–Aug.; Emmet and Schoolcraft.

APHANOCAPSA ELACHISTA W. & G. S. West. — Slow streams, bogs and ponds; frequent; July–Aug.; Cheboygan, Delta, Emmet and Schoolcraft.

Var. CONFERTA W. & G. S. West. — Lakes; frequent; Aug.; Ingham and Osceola.

APHANOCAPSA GREVILLEI (Hass.) Rabenh. — Ponds, bogs, lakes and ditches; frequent; May–July; Cheboygan, Emmet, Luce, Mecosta and Schoolcraft; also Schoolcraft (6).

APHANOCAPSA PULCHRA (Kütz.) Rabenh. — Ponds and lakes; common; March–Nov.; Cheboygan, Delta, Kalamazoo, Muskegon, Roscommon, St. Clair and Wayne.

APHANOCAPSA RIVULARIS (Carm.) Rabenh. — Small streams and ditches; frequent; May–June; Ottawa and Shiawassee.

APHANOTHECE CONFERTA Richter. — Swamp pools; rare; April; Branch.

APHANOTHECE MICROSCOPICA Näg. — Marsh pools; rare; July; Luce.

APHANOTHECE NIDULANS Richter. — Marsh and bog pools and slow streams; frequent; July–Aug.; Cheboygan and Ingham.

APHANOTHECE PALLIDA (Kütz.) Rabenh. — Ponds; rare; July; Cheboygan.

APHANOTHECE PRASINA A. Braun. — Bog pools; occasional; July; Cheboygan and Emmet.

APHANOTHECE SAXICOLA Näg. — Small lakes and ponds; rare; May–Aug.; Emmet and Schoolcraft; also Schoolcraft (6).

APHANOTHECE STAGNINA (Sprenger) A. Braun. — Lakes, ditches and rapid streams; frequent; April–July; Branch, Cheboygan, Emmet, Ingham and Livingston; also Oakland (6).

CHROOCOCCUS DISPERSUS (v. Keissler) Lemm. — Swamp and bog pools and small lakes; frequent; May–Aug.; Chippewa, Emmet, Ingham and St. Clair.

Var. MINOR G. M. Smith. — Lake shore; rare; June; Lapeer.

CHROOCOCCUS GIGANTEUS W. West. — Beach pools; rare; Aug.; Emmet.

CHROOCOCCUS LIMNETICUS Lemm. — Ponds and pools of swamps and bogs; frequent; May–Oct.; Cheboygan, Chippewa, Emmet, Houghton, Ingham, Livingston, Luce, Monroe, Muskegon, Ontonagon and Schoolcraft; also Monroe (5).

Var. DISTANS G. M. Smith. — Marsh pools; common; June–Aug.; Shiawassee.

Var. ELEGANS G. M. Smith. — Pools along streams; locally abundant; April; Calhoun.

Var. SUBSALSUS Lemm. — Marsh pools and lakes; abundant; May–Aug.; Gogebic, Houghton, Ingham, Monroe, Newaygo and Shiawassee; also Monroe (5).

CHROOCOCCUS MACROCOCCUS (Kütz.) Rabenh. — Ponds, lakes, slow streams, bogs and ditches; frequent; July–Aug.; Cheboygan, Chippewa, Emmet, Luce, Marquette and Schoolcraft.

CHROOCOCCUS MINUTUS (Kütz.) Näg. — Marshes, ditches, lake shores and rarely on damp earth; occasional; March–Aug.; Calhoun, Chippewa, Delta, Emmet, Ingham, Muskegon, Ottawa, Schoolcraft and Washtenaw; also Emmet (6).

CHROOCOCCUS MIPITANENSIS Geitler. — Cold streams; northern Michigan; collected by Dr. Metzelaar.

CHROOCOCCUS PALLIDUS Näg. — Springs; rare; July; Emmet.

CHROOCOCCUS TURGIDUS (Kütz.) Näg. — Marsh and bog pools, ponds, small lakes and slow streams; abundant; May–Aug.; Cheboygan, Delta, Emmet, Houghton, Ingham, Monroe, Muskegon, Shiawassee and Washtenaw; also Emmet and Muskegon (6) and Monroe (5).

COELOSPHAERIUM KUETZINGIANUM Näg. — Small streams; occasional; July–Aug.; Cheboygan, Monroe and Schoolcraft; also Monroe (5), Schoolcraft (6), and Wayne (2).

COELOSPHAERIUM NAEGELIANUM Unger. — Bog and small lakes; common; May–Oct.; Ingham, Kent, Monroe and Washtenaw; also Monroe (5).

DACTYLOCOCCOPSIS RAPHIDIOIDES Hansg. — Marsh pools; rare; May; Mecosta.

GLOEOCAPSA AERUGINOSA (Carm.) Kütz. — Ditches; rare; June; Tuscola.

GLOEOCAPSA ARENARIA (Hass.) Rabenh. — Bog pools, ditches and damp soil; common; July; Cheboygan and Houghton.

GLOEOCAPSA ATRATA (Turp.) Kütz. — Small lakes and bogs; occasional; July–Aug.; Cheboygan and Chippewa; also Chippewa (6).

GLOEOCAPSA CONGLOMERATA Kütz. — Ditches; rare; July; Cheboygan and Delta.

GLOEOCAPSA CREPIDINUM (Rabenh.) Thuret. — Bog pools; frequent; July; Cheboygan.

GLOEOCAPSA GIGAS W. & G. S. West. — Bog pools; common; July; Cheboygan.

GLOEOCAPSA GRANOSA (Berkeley) Kütz. — Swamps and small lakes; common; May–June; Barry and Ionia.

GLOEOCAPSA MELLEA Kütz. — Lake shore; rare; July; Cheboygan.

GLOEOCAPSA QUATERNATA (Bréb.) Kütz. — Lake shore; rare; July; Emmet.

GLOEOTHECE LUNATA W. & G. S. West. — Bog pools; rare; July; Chippewa.

GOMPHOSPHAERIA APONINA Kütz. — Lakes, swamps, bogs, pools and ditches; common; June–Aug.; Cheboygan, Clare, Emmet, Ingham, Lapeer, Livingston, Schoolcraft and Shiawassee; also Emmet and Schoolcraft (6).

Var. CORDIFORMIS Wolle. — Lake shores and beach pools; rare; July–Aug.; Cheboygan and Livingston.

GOMPHOSPHAERIA LACUSTRIS Chodat. — Small streams and lake shores; rare; July–Aug.; Cheboygan and Chippewa.

MERISMOPEDIA AERUGINEA Bréb. — Beach pools; occasional; July; Cheboygan.

MERISMOPEDIA CONVOLUTA Bréb. — Bog pools; rare; July; Cheboygan.

MERISMOPEDIA ELEGANS A. Braun. — Ponds, small streams and lakes; common; June–Oct.; Cheboygan, Monroe, Muskegon and Schoolcraft; also Monroe (5) and Emmet and Muskegon (6).

Var. MAJOR G. M. Smith. — Lake shores; common; July–Aug.; Washtenaw.

MERISMOPEDIA GLAUCA (Ehrenb.) Näg. — Bogs, small lakes and brooks; common; July–Aug.; Cheboygan, Chippewa, Livingston, Monroe and Washtenaw; also Monroe (5), Chippewa and Emmet (6) and Wayne (2).

MERISMOPEDIA PUNCTATA Meyen. — Ponds and lakes; common; July–Aug.; Delta and Livingston.

MERISMOPEDIA TENUISSIMA Lemm. — Lakes, ponds and ditches; common; May–Aug.; Cheboygan, Ingham, Lapeer, Livingston, Schoolcraft and Washtenaw; also Monroe (5) and Emmet (6).

MICROCYSTIS AERUGINOSA Kütz. — Cold streams and lakes; common; July–Sept.; Cheboygan, Ingham, Jackson, Livingston, Roscommon and Washtenaw; also Monroe (5).

Var. MAJOR (Wittr.) G. M. Smith. — Lakes, bogs and ditches; common; May–July; Houghton, Iron, Kent and Newaygo; also Monroe (5).

MICROCYSTIS DONNELLII Wolle. — Lake shores; frequent; Aug.; Cheboygan.

MICROCYSTIS ELABENS (Menegh.) Kütz. — Rivers; rare; Dec.; Macomb.

MICROCYSTIS FLOS-AQUAE (Wittr.) Kirchner. — Lakes, beach pools, marshes, ditches and small streams; common; April–Aug.; Cheboygan, Houghton, Ingham, Montcalm, Schoolcraft, St. Joseph and Washtenaw.

MICROCYSTIS ICHTHYOBLABE Kütz. — Small lakes and bogs; rare; July–Aug.; Cheboygan.

MICROCYSTIS PULVEREA (Wood) Migula. — Swamp pools and small lakes; common; May–Aug.; Emmet, Montcalm and Washtenaw.

Var. INCERTA Lemm. — Lake shores, bogs, ponds and slow streams; abundant; May–Aug.; Allegan, Barry, Chippewa, Delta, Ingham, Kalamazoo, Livingston, Newaygo, Osceola, Schoolcraft and Washtenaw.

Microcystis stagnalis Lemm. — Bog pools; rare; April; Marshall and Calhoun.

Synechocystis aquatilis Sauvageau. — Small streams; rare; Aug.; Washtenaw.

CHAMAESIPHONALES

Chamaesiphonaceae

Chamaesiphon incrustans Grun. — Marsh pools, ditches and small streams; locally abundant; July–Aug.; Calhoun and Schoolcraft.

Xenococcus kerneri Hansg. — Bog pools and small streams; rare; May–July; Houghton and Montcalm.

Xenococcus schousboei Thuret. — Lake shores; rare; July–Aug.; Washtenaw.

HORMOGONEALES

Oscillatoriaceae

Dasygloea amorpha Berkeley. — Bog pools; rare; July; Cheboygan.

Lyngbya aerugineo-coerulea (Kütz.) Gomont. — Ditches, lake shores, bog pools and small streams; occasional; July–Aug.; Cheboygan and Mackinac.

Lyngbya aestuarii (Mert.) Liebm. — Ponds and small lakes; occasional; June; Berrien; also Berrien and Van Buren (6).

Lyngbya arachnoidea Kütz. — Small streams; rare; July–Aug.; Cheboygan and Mackinac.

Lyngbya birgei G. M. Smith. — Lake shores and springs; common; June–Aug.; Cheboygan, Ingham, Iron and Roscommon.

Lyngbya cliarensis W. & G. S. West. — Ditches; rare; Aug.; Schoolcraft.

Lyngbya cryptovaginata Schkorbatow. — Swamps and marsh pools; common; May–July; Newaygo and Schoolcraft.

Lyngbya digueti Gomont. — Lake shores; rare; Aug.; Emmet.

Lyngbya distincta (Nordst.) Schmidle. — Small streams; rare; July; Cheboygan.

LYNGBYA HIERONYMUSII Lemm. — Lake shores; occasional; May; Kent.

LYNGBYA MAJOR Menegh. — Lake shores and small streams; occasional; June–Aug.; Jackson, Mackinac and Oakland.

LYNGBYA MAJUSCULA (Dillwyn) Harvey. — Lake shores; locally abundant; July; Cheboygan.

LYNGBYA MARTENSIANA Menegh. — Beach pools; rare; July–Aug.; Emmet.

LYNGBYA MURRAYI W. & G. S. West. — Swamp pools; common; May; Kalamazoo.

LYNGBYA NANA Tilden. — Beach pools and small streams; locally common; July–Aug.; Emmet.

LYNGBYA SPIRULINOIDES Gomont. — Beach pools; common; July–Aug.; Cheboygan and Emmet.

LYNGBYA SUBCONFERVOIDES Borge. — Lake shores; rare; Aug.; Livingston.

LYNGBYA VERSICOLOR (Wartmann) Gomont. — Beach and bog pools; rare to common; July–Aug.; Cheboygan and Emmet.

MICROCOLEUS DELICATULUS W. & G. S. West. — Beach pools; common; July–Aug.; Emmet.

MICROCOLEUS LACUSTRIS (Rabenh.) Farlow. — Schoolcraft (6).

OSCILLATORIA ACUTISSIMA Kufferath. — Marsh pools and ditches; rare; July–Aug.; Clare, Luce and Ontonagon.

OSCILLATORIA AGARDHII Gomont. — Shaded streams; frequent; June–July; Gogebic and Roscommon.

OSCILLATORIA AMOENA (Kütz.) Gomont. — Cold spring; rare; July; Emmet.

OSCILLATORIA AMPHIBIA Ag. — Pools; occasional; July; Schoolcraft.

OSCILLATORIA ANGUSTISSIMA W. & G. S. West. — Beach pools and small lakes; common; July–Sept.; Baraga, Emmet, Houghton and Jackson.

OSCILLATORIA ANNAE van Goor. — Shaded pools and small streams; frequent; April; Oakland.

OSCILLATORIA BEGGIATOIFORMIS (Grun.) Gomont. — Cold springs; locally abundant; July; Houghton.

OSCILLATORIA CHALYBEA Mert. — Creeks; common; July–Aug.; Cheboygan and Schoolcraft; also Schoolcraft (6).

OSCILLATORIA CHLORINA Kütz. — Lake shores; frequent; July–Nov.; Cheboygan, Emmet and Washtenaw.

OSCILLATORIA CURVICEPS Ag. — Ditches and pools; frequent; May–Sept.; Jackson and Ottawa.

OSCILLATORIA DEFLEXA W. & G. S. West. — Ditches; rare; July; Ontonagon.

OSCILLATORIA FORMOSA Bory. — Cold springs and pools; rare; July; Emmet.

OSCILLATORIA GEMINATA Menegh. — Small pools, bogs and lakes; abundant; July; Cheboygan and Ontonagon.

OSCILLATORIA GLOEOPHILA Grunow. — Ponds and bogs; abundant; April–July; Oakland and Ontonagon.

OSCILLATORIA KOETTLITZI Fritsch. — Ponds; abundant; May; Wayne.

OSCILLATORIA LIMOSA Kütz. — Practically all habitats; widely distributed and abundant; March–Oct.; in nearly all counties visited and probably present in all.

OSCILLATORIA MINNESOTENSIS Tilden. — Bog pools; rare; July; Cheboygan.

OSCILLATORIA MOUGEOTII Kütz. — Lake shores, bogs, streams and ponds; abundant; March–Aug.; in most counties visited and probably present in all.

OSCILLATORIA NIGRA Vaucher. — Pools and streams; common; July–Aug.; Cheboygan, Delta and Washtenaw.

OSCILLATORIA ORNATA Kütz. — Lake shore; occasional; July; Cheboygan.

OSCILLATORIA PLANCTONICA Woloszynska. — Small streams, ditches and ponds; abundant; May–July; Chippewa, Dickinson, Houghton, Iron, Lapeer, Shiawassee, Tuscola and Wayne.

OSCILLATORIA PRINCEPS Vaucher. — Lakes, ponds and streams; abundant; April–Aug.; Branch, Cheboygan, Chippewa, Delta, Genesee, Houghton, Ingham, Iron, Luce and Ontonagon; also Chippewa (6).

OSCILLATORIA PROLIFICA (Greville) Gomont. — Monroe (5).

OSCILLATORIA SANCTA Kütz. — Lake shore; rare; Aug.; Washtenaw.

OSCILLATORIA SPLENDIDA Greville. — Bog pools and slow streams; common; July–Aug.; Cheboygan and Washtenaw.

OSCILLATORIA SUBTILISSIMA Kütz. — Ponds and slow streams; common; April–July; Branch, Emmet, Ontonagon and Shiawassee.

OSCILLATORIA TENUIS Ag. — Nearly all habitats; abundant; May–Aug.; probably in all counties; also Wayne (2).

OSCILLATORIA TEREBRIFORMIS (Ag.) Gomont. — Bogs, streams and lake shores; common; July–Aug.; Cheboygan and Washtenaw.

OSCILLATORIA TRICHOIDES Szafer. — Shallow stream; rare; July; Ontonagon.

PHORMIDIUM CORIUM (Ag.) Gomont. — Bog pools; rare; July; Cheboygan.

PHORMIDIUM JADINIANUM Gomont. — Lake shores; abundant; May; Montcalm.

SCHIZOTHRIX BRAUNII Gomont. — Lake shore; common; Aug.; Emmet.

SCHIZOTHRIX HYALINA Kütz. — Lake shore; abundant; July; Cheboygan.

SPIRULINA CORAKIANA Playfair. — Bog pools; abundant; July; Baraga.

SPIRULINA GOMONTIANA (Setchell) Geitler. — Lake shore; rare; Aug.; Ingham.

SPIRULINA OSCILLARIOIDES Turp. — Wayne (2).

SPIRULINA SUBTILISSIMA Kütz. — Swamp pools and lake shores; frequent; June–July; Baraga, Lapeer and Schoolcraft.

SPIRULINA TENUISSIMA Kütz. — Slow stream; rare; Aug.; Cheboygan.

NOSTOCACEAE

ANABAENA CATENULA (Kütz.) Bornet & Flah. — Swamp and beach pools, ditches and damp soil; common; May–Aug.; Chippewa, Emmet, Gogebic, Houghton, Newaygo and Shiawassee.

Anabaena circinalis (Kütz.) Hansg. — Lakes; rare; July–Aug.; Cheboygan, Chippewa and Livingston; also Chippewa (6).

Anabaena contorta Bach. — Small pools; frequent; July; Iron.

Anabaena flos-aquae (Lyng.) Bréb. — Lakes and bogs; abundant as a "water bloom"; July–Aug.; Cheboygan and Washtenaw; also Oakland (6).

Anabaena inaequalis (Kütz.) Bornet & Flah. — Small streams, lake shores and pools; frequent; May–Aug.; Cheboygan, Houghton, Ingham, Livingston, Luce, Montcalm and Shiawassee.

Anabaena laxa A. Braun. — Beach and bog pools and ponds; abundant; July–Sept.; Cheboygan, Houghton and Jackson.

Anabaena lemmermanni P. Richter. — Lakes, beach pools and bogs; frequent to abundant; July–Sept.; Cheboygan, Emmet, Ingham and Jackson.

Anabaena oscillarioides Bory. — Slow streams, lakes, bogs, pools and swamps; rare; June–Aug.; Cheboygan, Emmet and Luce.

Anabaena subrigida (Wood) De Toni. — Lake; rare; July; Cheboygan.

Anabaena thwaitesii (Ralfs) Cooke. — Wayne (2).

Anabaena torulosa (Carm.) Lagerh. — Small streams, lake shore and swamp pools; occasional to abundant; May–July; Cheboygan, Mecosta and Schoolcraft.

Anabaena variabilis Kütz. — Bogs and swamps; abundant; May–July; Calhoun, Cheboygan, Chippewa, Houghton, Ingham, Kalamazoo and Mecosta; also Berrien (6).

Aphanizomenon flos-aquae (Linné) Ralfs. — Lakes, bogs and ditches; occasional; June–Aug.; Cheboygan, Ingham and Shiawassee.

Cylindrospermum licheniforme (Bory) Kütz. — Bog pools; abundant; July; Houghton.

Cylindrospermum macrospermum Kütz. — Wayne (2).

Cylindrospermum majus Kütz. — Bog pools; rare; July; Cheboygan.

Cylindrospermum minutissimum Collins. — Bog pools; frequent; July; Houghton.

Cylindrospermum minutum Wood. — Roadside pools and bogs; common; July–Aug.; Cheboygan and Emmet.

Cylindrospermum musicola Kütz. — Bog pools; rare; July–Aug.; Cheboygan and Houghton.

Cylindrospermum punctatum Woron. — Marshes; abundant; May; Kalamazoo.

Cylindrospermum stagnale (Kütz.) Bornet & Flah. var. angustum Smith. — Damp soil; occasional; July; Delta.

Cylindrospermum vouki Pevalek. — Ditches; frequent; July; Ontonagon.

Nodularia harveyana (Thwaites) Thuret. — Lakes; rare; July; Livingston.

Nodularia paludosa Wolle. — Slow streams and swamp pools; frequent; May–Aug.; Cheboygan, Montcalm and Washtenaw.

Nodularia sphaerocarpa Bornet & Flah. — Marsh pools; frequent; June; Shiawassee.

Nodularia spumigena Mert. — Swamp pools; rare; April; Branch.

Nostoc caeruleum Lyng. — Beach pools, bogs and small streams; frequent; July; Cheboygan.

Nostoc comminutum Kütz. — Bog pools, rarely cold lakes; occasional; July; Cheboygan, Delta and Emmet.

Nostoc commune Vaucher. — Bog and beach pools; frequent; July–Aug.; Cheboygan and Emmet; also Wayne (2).

Nostoc disciforme Fritsch. — Swamps and pool in gravel pit; occasional; July; Chippewa and Delta.

Nostoc ellipsosporum (Desm.) Rabenh. — Wayne (4).

Nostoc fucescens Fritsch. — Beach pools; abundant; Aug.; Washtenaw.

Nostoc humifuscum Carm. — Beach pools; rare; July; Emmet.

Nostoc kihlmanni Lemm. — Slow streams; abundant; April; St. Clair.

Nostoc microscopicum Carm. — Pools; rare; July; Emmet.

Nostoc muscorum Ag. — Lake shore; occasional; July; Emmet.

Nostoc piscinale Kütz. — Bog pools; frequent; July; Cheboygan.

NOSTOC PRUNIFORME Ag. — Small lakes and marshes; occasional; July; Emmet and Schoolcraft.

NOSTOC PUNCTIFORME (Kütz.) Hariot. — Marsh pools; frequent; June–July; Houghton and Shiawassee.

NOSTOC RIVULARE Kütz. — Pool; rare; July; Cheboygan.

NOSTOC SPHAERICUM Vaucher. — Lakes; abundant; July; Ontonagon; also Wayne (1).

NOSTOC SPONGIAEFORME Ag. — Bog pools; occasional; July; Cheboygan.

NOSTOC VERRUCOSUM (Linné) Vaucher. — Lake shore; rare; July; Emmet.

SCYTONEMATACEAE

MICROCHAETE SPIRALIS Ackley. — Ditch; occasional; July; Schoolcraft.

SCYTONEMA ALATUM (Berkeley) Borzi. — Beach pools and bogs; occasional; July–Aug.; Cheboygan and Emmet.

SCYTONEMA AUSTINII Wood. — Lake shore; abundant; Aug.; Emmet.

SCYTONEMA HOFMANNI Ag. — Beach and bog pools and lakes; frequent; July–Aug.; Cheboygan and Emmet.

SCYTONEMA MIRABILE (Dillwyn) Bornet. — Bog and beach pools; frequent; July–Aug.; Cheboygan.

SCYTONEMA MYOCHROUS (Dillwyn) Ag. — Lake shores and bog pools; frequent; Aug.; Emmet.

SCYTONEMA OCELLATUM Lyng. — Oakland (6).

SCYTONEMA SIMMERI Schmidle. — Slow stream; occasional; Sept.; Macomb.

SCYTONEMA TOLYPOTRICHOIDES Kütz. — Lake shores, beach pools and bogs; frequent; July–Aug.; Cheboygan and Emmet.

TOLYPOTHRIX DISTORTA Kütz. — Lake shores; rare; March–Aug.; Ingham and Wayne.

TOLYPOTHRIX LANATA (Desvaux) Wartmann. — Bogs, marshes, swamps and lakes; abundant; May–Sept.; Calhoun, Cheboygan, Chippewa, Emmet, Genesee, Houghton, Iron, Kalamazoo, Kalkaska, Livingston and Luce; also Emmet (6).

TOLYPOTHRIX LIMBATA Thuret. — Bogs, ditches and pools; frequent; June–Aug.; Berrien, Houghton and Mackinac; also Berrien and Cheboygan (6).

Tolypothrix penicillata (Ag.) Thuret. — Lake shores; occasional; July–Aug.; Emmet and Livingston.

Tolypothrix rivularis Hansg. — Small stream; rare; July; Chippewa.

Tolypothrix tenuis Kütz. — Lakes, ponds, bogs and beach pools; frequent; July–Aug.; Cheboygan, Emmet, Houghton, Luce, Osceola and Wexford; also Berrien, Houghton and Muskegon (6).

Rivulariaceae

Calothrix clavata G. S. West. — Marsh pools; rare; June; Shiawassee.

Calothrix epiphytica W. & G. S. West. — Marsh pools; occasional; June; Shiawassee.

Calothrix gracilis Fritsch. — Marsh pools; rare; June; Shiawassee.

Calothrix minima Frémy. — Shaded stream; rare; May; Ottawa.

Calothrix parietina (Näg.) Thuret. — Beach pools; rare; July–Aug.; Emmet.

Calothrix sejunctum Wood. — Bog pools; rare; July; Cheboygan; also "Carp River" (8).

Calothrix stagnalis Gomont. — Bog pools; occasional; Aug.; Ingham.

Calothrix turgida Wolle. — Lake; rare; July; Emmet.

Dichothrix hosfordii (Wolle) Bornet. — Lake shore and beach pools; frequent; July–Aug.; Emmet and Wayne.

Dichothrix orsiniana (Kütz.) Bornet & Flah. — Lake shore; occasional; July; Emmet.

Gloeotrichia echinulata (J. E. Smith) Richter. — Lake shore; frequent; Aug.–Sept.; Ingham and Jackson.

Gloeotrichia natans (Hedwig) Rabenh. — Lakes; rare; July–Aug.; Cheboygan and Chippewa; also Cheboygan and Emmet (6).

Gloeotrichia pisum (Ag.) Thuret. — Lake shores; abundant;

July–Aug.; Cheboygan and Macomb; also Chippewa, Emmet, Oakland and Van Buren (6).

RIVULARIA AQUATICA De Wildeman. — Lake shore; frequent; Sept.; Oakland.

RIVULARIA BECCARIANA (De Not.) Bornet & Flah. — Lake shore; occasional; Aug.; Ingham.

RIVULARIA BOREALIS Richter. — Lake shore; rare; June; Lapeer.

RIVULARIA COMPACTA Collins. — Lake shore; abundant; July–Aug.; Cheboygan, Chippewa, Emmet, Livingston, Schoolcraft and Washtenaw; also Chippewa (6).

RIVULARIA DURA Roth. — Lake shores; abundant; July; Cheboygan; also Wayne (2).

RIVULARIA GLOBICEPS G. S. West. — Lake shore; rare; July; Chippewa.

STIGONEMATACEAE

HAPALOSIPHON FLEXUOSUS Borzi. — Bog and swamp pools; frequent; July–Aug.; Cheboygan and Kalkaska.

HAPALOSIPHON FONTINALIS (Ag.) Bornet. — Beach pools and bog; frequent; July–Aug.; Cheboygan.

STIGONEMA HORMOIDES (Kütz.) Bornet & Flah. — Bog and beach pools; common; July–Aug.; Cheboygan and Ingham.

STIGONEMA INFORME Kütz. — Bog pools and ponds; frequent; July–Aug.; Cheboygan and Mackinac; also Cheboygan (6).

STIGONEMA MAMILLOSUM (Lyng.) Ag. — Beach pools; rare; July; Cheboygan.

STIGONEMA OCELLATUM (Dillwyn) Thuret. — Bog pools; frequent; July–Aug.; Cheboygan.

STIGONEMA TURFACEUM (Berk.) Cooke. — Beach pools; abundant; Aug.; Emmet and Livingston.

CHRYSOPHYCEAE

HYMENOMONADALES

EUHYMENOMONADACEAE

SYNURA UVELLA Ehrenb. — Beach pools and swamps; frequent; July–Aug.; Cheboygan.

OCHROMONADALES

DINOBRYACEAE

DINOBRYON BAVARICUM Imhof. — Lake; occasional; July; Livingston.

DINOBRYON CRENULATUM W. & G. S. West. — Lake; rare; June; Lapeer.

DINOBRYON SERTULARIA Ehrenb. — Lakes, rivers, small streams, marshes and bog pools; abundant; May–June; Calhoun, Delta, Ingham, Kent and Livingston; also Monroe (5).

RHODOPHYCEAE

NEMALIONALES

HELMINTHOCLADIACEAE

BATRACHOSPERMUM MONILIFORME Roth. — Cold streams and bogs; frequent; July–Aug.; Chippewa, Delta and Emmet; also "Gary," Michigan (8).

BATRACHOSPERMUM VAGUM (Roth) Ag. — Bog pools; frequent; Aug.; Cheboygan.

HETEROKONTAE

HETEROCOCCALES

CHLOROBOTRYDACEAE

CHLOROBOTRYS REGULARIS (W. West) Bohlin. — Pools, marshes and bogs; April–Aug.; frequent; Branch, Cheboygan, Houghton and Ingham; also Cheboygan (6).

BOTRYOCOCCACEAE

BOTRYOCOCCUS BRAUNII Kütz. — Lakes, creeks, rivers, marshes, bogs and ditches; abundant; June–Aug.; found in nearly all counties and probably present in all; also Monroe (5) and Muskegon and Schoolcraft (6).

BOTRYOCOCCUS PROTUBERANS W. & G. S. West var. MINOR G. M. Smith. — Rivers and gravel pit; July–Oct.; occasional; Delta; also Monroe (5).

BOTRYOCOCCUS SUDETICUS Lemm. — Lake; rare; Aug.; Washtenaw.

CHLOROTHECIACEAE

CHARACIOPSIS ACUTA (A. Braun) Borzi. — Pools along lake; occasional; May; Allegan.

CHARACIOPSIS ELLIPSOIDEA G. S. West. — Lake; occasional; May; Allegan.

CHARACIOPSIS PYRIFORMIS (A. Braun) Borzi. — Cold stream; rare; July; Delta.

OPHIOCYTIACEAE

OPHIOCYTIUM ARBUSCULA (A. Braun) Rabenh. — Streams, ditches and pools; abundant; April–June; Barry, Chippewa, Ionia, Kalamazoo, Livingston, Mecosta, Montcalm, Newaygo, Ottawa and Van Buren.

OPHIOCYTIUM CAPITATUM Wolle. — Ditches, swamps, bogs and lake shores; common; May–Aug.; Cheboygan, Houghton, Kent, Muskegon and Oakland.

OPHIOCYTIUM COCHLEARE (Eichw.) A. Braun. — Marshes, bogs, swamps, ditches, beach pools and lake shores; abundant; April–Aug.; present in eighty-four counties and probably in all; also Emmet, Schoolcraft and Van Buren (6).

OPHIOCYTIUM DESERTUM Printz. — Swamps, bogs and marshes; locally common; May–June; Barry, Calhoun, Kent, Mecosta and Newaygo.

OPHIOCYTIUM GRACILIPES (A. Braun) Rabenh. — Bog; rare; April; Van Buren.

OPHIOCYTIUM MAJUS Näg. — Ditches, bogs and swamps; common; April–July; Branch, Cheboygan, Mackinac, Monroe, Montcalm, Ottawa, Sanilac, Shiawassee and Van Buren.

OPHIOCYTIUM MUCRONATUM (A. Braun) Rabenh. — Swamp; rare; May; Mecosta.

Ophiocytium parvulum (Perty) A. Braun. — Ditches, swamps, bogs, marshes, slow streams, lake shores, beach pools and ponds; abundant; May–Aug.; present in ninety-one per cent of all counties visited and probably present in all.

HETEROTRICHALES

Tribonemaceae

Tribonema bombycinum (Ag.) Derbès & Sol. — In all aquatic habitats studied; abundant; Feb.–Nov.; found in all counties visited and probably present in all; also Allegan, Berrien, Cheboygan, Keweenaw and Schoolcraft (6).

Forma minor (Wille) G. S. West. — Slow streams, ditches and marsh pools; frequent; April–June; Calhoun, Monroe and Van Buren.

Forma tenue Hazen. — In all aquatic habitats studied; abundant; Feb.–Nov.; in all counties visited and probably present in all; also Van Buren (6).

Tribonema utriculosum Hazen. — Ditches, marsh, swamp pools, lake shores and rivers; abundant; April–Oct.; Branch, Cheboygan, Ottawa, Shiawassee and Wayne; also Allegan, Berrien, Oakland and Schoolcraft (6).

CHLOROPHYCEAE

ISOKONTAE

VOLVOCALES

Volvocaceae

Eudorina elegans Ehrenb. — Marshes, bogs, lakes, ditches and small streams; abundant; May–Aug.; found in seventeen counties and probably present in most; also Monroe (5) and Berrien and Schoolcraft (6).

Gonium pectorale Müller. — Ditches, marshes, beach pools and bogs; common; March–July; Cheboygan, Newaygo and Wayne; also Berrien (6).

PANDORINA MORUM Bory. — Lakes, streams, ditches, marshes, bogs and swamps; abundant; April–Oct.; Berrien, Branch, Calhoun, Cheboygan, Emmet, Houghton, Ingham, Iron, Jackson, Livingston, Luce, Monroe, Newaygo, Roscommon and Van Buren; also Monroe (5) and Berrien and Van Buren (6).

VOLVOX AUREUS Ehrenb. — Swamp and beach pools; common; May–July; Barry and Cheboygan.

VOLVOX GLOBATOR (Linné) Ehrenb. — Lake shore; frequent; June–Aug.; Barry, Ingham and Livingston.

VOLVOX MONONAE G. M. Smith. — Swamp and roadside pools; frequent; May–July; Barry, Delta and Newaygo.

CHLAMYDOMONADACEAE

CHLAMYDOMONAS MUCICOLA Schmidle. — Polluted water of lake shore; frequent; Aug.; Cheboygan.

CHLAMYDOMONAS SNOWII Printz. — Polluted water; frequent; May–Aug.; Emmet and Oakland.

CHLOROCOCCALES

PALMELLACEAE

APIOCYSTIS BRAUNIANA Näg. — Ditches and lake shores; rare; June–Aug.; Chippewa; also Van Buren (5).

ASTEROCOCCUS LIMNETICUS G. M. Smith. — Lake; occasional; Aug.; Livingston.

ASTEROCOCCUS SUPERBUS (Cienk.) Scherffel. — Swamp pools; rare; April; Van Buren.

GLOEOCYSTIS GIGAS (Kütz.) Lagerh. — All aquatic habitats visited; abundant; May–Sept.; in nearly all counties visited and probably present in all; also Berrien, Mackinac and Van Buren (6).

GLOEOCYSTIS LIMNETICUS G. M. Smith. — Bog pools; rare; Aug.; Chippewa.

GLOEOCYSTIS VESICULOSA Näg. — Ditches, marshes, pools and bogs; frequent; July–Aug.; Cheboygan, Chippewa and Houghton.

GLOEOCYSTOPSIS LIMNETICUS G. M. Smith. — Bog pools; occasional; July; Chippewa.

PALMODICTYON VARIUM (Näg.) Lemm. — Pools, ditches and bays; frequent; July–Aug.; Baraga, Cheboygan and Schoolcraft; also Schoolcraft (6).

PALMODICTYON VIRIDE Kütz. — Marsh and bog pools; rare; April–July; Cheboygan, Shiawassee and Wayne.

PLANKTOSPHAERIA GELATINOSA G. M. Smith. — Creeks, ditches and pools; occasional; June–Aug.; Chippewa, Emmet, Iron, Lapeer and Washtenaw.

SCHIZOCHLAMYS GELATINOSA A. Braun. — Lake shore; frequent; Aug.; Washtenaw.

SPHAEROCYSTIS SCHROETERI Chodat. — Water trough, small lakes, streams and rarely in alkaline bogs; frequent; July–Aug.; Cheboygan, Chippewa, Houghton, Ingham and Schoolcraft.

TETRASPORA CYLINDRICA (Wahlenb.) Ag. — River; rare; July; Emmet; also Keweenaw (6).

TETRASPORA GELATINOSA (Vauch.) Desvaux. — Cold streams and ponds; abundant; April–July; Branch, Cass, Cheboygan, Chippewa, Emmet, Houghton, Iron, Kent, Lenawee, Luce, Monroe, Newaygo and Ontonagon.

TETRASPORA LIMNETICA W. & G. S. West. — Bog pools and bog streams; occasional; July–Aug.; Emmet; also Schoolcraft (6).

TETRASPORA LUBRICA (Roth) Ag. — Cold streams, ditches and pools; abundant; May–Aug.; Allegan, Baraga, Branch, Cheboygan, Delta, Emmet, Hillsdale, Houghton, Monroe, Newaygo, Ottawa, Saginaw and Sanilac; also Allegan, Chippewa and Van Buren (6).

HYDRODICTYACEAE

HYDRODICTYON RETICULATUM (L.) Lagerh. — Slow streams; abundant; April–Aug.; Newaygo, Washtenaw and Wayne.

PEDIASTRUM ANGULOSUM (Ehrenb.) Menegh. — Muskegon (6).

PEDIASTRUM BIRADIATUM Meyen. — Beach pools; occasional; July; Cheboygan.

PEDIASTRUM BORYANUM (Turp.) Menegh. — Pools, rivers and lake shores; abundant; May–Oct.; Cheboygan, Emmet, Gogebic, Kalamazoo, Lapeer, Monroe, Roscommon and Schoolcraft; also Monroe (5), Emmet and Schoolcraft (6) and Wayne (2).

Var. GRANULATUM (Kütz.) A. Braun. — Lake shore; rare; June; Roscommon;

Var. LONGICORNE Racib. — Lake shore; rare; July; Chippewa.

Var. UNDULATUM Wille. — Lake; rare; July; Roscommon.

PEDIASTRUM CONSTRICTUM Hass. — Wayne (2).

PEDIASTRUM DUPLEX Meyen. — River, beach pools and lake shores; locally common; July–Oct.; Cheboygan, Chippewa, Livingston, Washtenaw and Wayne; also Monroe (5) and Wayne (2).

Var. BRACHYLOBUM A. Braun. — Bog pools; rare; July; Cheboygan.

Var. CLATHRATUM (A. Braun) Lagerh. — Lake shores; occasional; July–Aug.; Cheboygan and Chippewa; also Monroe (5) and Chippewa (6).

Var. GRACILLIMUM W. & G. S. West. — Lake shore; rare; Aug.; Ingham.

Var. RETICULATUM Lagerh. — Monroe (5).

PEDIASTRUM INTEGRUM Näg. — Lake shore; rare; June; Roscommon.

PEDIASTRUM KAWRAISKYI Schmidle. — Lake shore; rare; June; Roscommon.

PEDIASTRUM TETRAS (Ehrenb.) Ralfs. — Lakes, pools and rivers; abundant; May–Oct.; Allegan, Cheboygan, Emmet, Ingham, Kalamazoo, Muskegon and Newaygo; also Monroe (5), Muskegon (6) and Wayne (2).

Var. TETRAODON (Corda) Hansg. — Creeks, springs and rivers; rare; July–Aug.; Cheboygan, Manistique and Washtenaw.

PEDIASTRUM TRICORNUTUM Borge. — Muskegon (6).

CHLOROCOCCACEAE

CHARACIUM ACUMINATUM A. Braun. — Bogs; rare; July; Cheboygan.

CHARACIUM AMBIGUUM Herman. — Bogs, beach pools and swamps;

frequent; May–July; Branch, Cheboygan, Mecosta and Saginaw.

CHARACIUM DEBARYANUM (Reinsch) De Toni. — "Michigan" (3).

CHARACIUM FALCATUM Schröder. — Marsh pools and lake shores; occasional; May–June; Kent and Shiawassee.

CHARACIUM HETEROMORPHUM Reinsch. — Ditches; occasional; May–June; Newaygo and Schoolcraft.

CHARACIUM LIMNETICUM Lemm. — Lake shore; rare; Aug.; Ingham.

CHARACIUM OBTUSUM A. Braun. — Marsh pools and brooks; frequent; April–July; Monroe and Shiawassee.

CHARACIUM OPERCULUM Ackley. — Pools; rare; July; Luce.

CHARACIUM PRINGSHEIMII A. Braun. — Cold streams and marsh pools; abundant; May–June; Newaygo, Saginaw and Shiawassee.

CHARACIUM ROSTRATUM Reinsch. — Muskegon (3).

CHARACIUM SESSILE Herm. — Bog pools and lake shores; frequent; May–July; Cheboygan, Kalamazoo and Kent.

CHARACIUM SIEBOLDII A. Braun. — Slow brooks, bogs and pools; occasional; April–July; Delta, Houghton and St. Joseph.

CHARACIUM STIPITATUM (Bachm.) Wille. — Bogs; occasional; July–Aug.; Cheboygan.

CHLOROCOCCUM INFUSIONUM (Schrank) Menegh. — Ditches and bogs; frequent; July–Aug.; Ingham and Schoolcraft.

HALOSPHAERACEAE

EREMOSPHAERA VIRIDIS De Bary forma MAJOR G. T. Moore. — Bogs; frequent; July–Aug.; Cheboygan and Emmet.

Var. MINOR G. T. Moore. — Bogs; rare; Aug.; Cheboygan.

DICTYOSPHAERIACEAE

DICTYOSPHAERIUM EHRENBERGIANUM Näg. — Lake shore; rare; May; Muskegon.

DICTYOSPHAERIUM PULCHELLUM Wood. — Rivers, lake shores, bogs, marshes and swamps; frequent; May–Aug.; Cheboygan, Emmet, Ingham, Mecosta and Washtenaw; also Monroe (5) and Chippewa (6).

DIMORPHOCOCCUS CORDATUS Wolle. — Bog; frequent; Aug.; Cheboygan.

DIMORPHOCOCCUS LUNATUS A. Braun. — Muskegon (6).

WESTELLA BOTRYOIDES (W. West) De Wildeman. — Cold streams, lake shores, bogs and swamps; frequent; Cheboygan, Livingston, Newaygo, Roscommon and Schoolcraft.

Var. MAJOR G. M. Smith. — Lake; frequent; Aug.; Livingston.

WESTELLA LINEARIS G. M. Smith. — Monroe (5).

AUTOSPORACEAE

ACTINASTRUM GRACILLIMUM G. M. Smith. — Lake; abundant; June; Lapeer.

ACTINASTRUM HANTZSCHII Lagerh. — Lake; rare; June; Roscommon.

ANKISTRODESMUS BRAUNII (Näg.) Brunn. — Lake; frequent; Aug.; Emmet.

ANKISTRODESMUS CONVOLUTUS Corda. — Bogs; rare; Aug.; Cheboygan.

ANKISTRODESMUS FALCATUS (Corda) Ralfs. — Lake and bogs; frequent; May–Aug.; Cheboygan and Emmet; also Berrien (6) and Wayne (2).

Var. ACICULARIS (A. Braun) G. S. West. — Margin of streams; occasional; July; Branch.

Var. SPIRALE (Turner) W. & G. S. West. — Lake shore, bogs and rivers; occasional; July–Aug.; Cheboygan and Emmet; also Berrien (6).

ANKISTRODESMUS SPIRALIS (Turner) Lemm. — Lake shore, bogs and river; occasional; July–Aug.; Cheboygan.

CHLORELLA MINIATA (Näg.) Oltm. — Gravel pit; frequent; June; Tuscola.

CHLORELLA VULGARIS Beyerinck. — Lake shores, gravel pit and swamps; frequent; May–Aug.; Calhoun, Chippewa, Delta, Ingham and Monroe.

COELASTRUM CAMBRICUM Archer. — Lake shores and bog pools; occasional; June–Aug.; Cheboygan and Newaygo; also Emmet and Muskegon (6).

COELASTRUM MICROPORUM Näg. — Lake shore, rivers, bogs and pools; frequent; May–Sept.; Ingham, Jackson, Monroe, Newaygo, Schoolcraft, Tuscola and Washtenaw; also Monroe (5) and Emmet and Schoolcraft (6).

COELASTRUM PROBOSCIDEUM Bohlin. — Berrien (6).

COELASTRUM RETICULATUM (Dang.) Senn. — Monroe (5).

COELASTRUM SCABRUM Reinsch. — Bogs and small pools; occasional; July–Aug.; Cheboygan and Mackinac; also Cheboygan and Emmet (6).

COELASTRUM SPHAERICUM Näg. — Lake shores and bogs; occasional; June–Aug.; Cheboygan and Schoolcraft; also Emmet, Muskegon and Schoolcraft (6).

CRUCIGENIA QUADRATA Morren. -- Bogs; rare; July; Cheboygan.

CRUCIGENIA RECTANGULARIS (Näg.) Gay. — Lakes, rivers and ditches; common; May–Oct.; Livingston and Monroe; also Monroe (5) and Berrien (6).

EXCENTROSPHAERA VIRIDIS G. T. Moore. — Bog; abundant; July; Cheboygan.

GLOEOTAENIUM LOITLESBERGERIANUM Hansg. — Lakes and pools; occasional; May–Aug.; Ingham and Kent.

KIRCHNERIELLA CONTORTA (Schmidle) Bohlin. — Ditch; rare; July; Schoolcraft.

KIRCHNERIELLA LUNARIS (Kirchner) Moeb. — Bog and beach pools; occasional; July–Aug.; Chippewa and Emmet.

Var. DIANAE Bohlin. — Lake shores; occasional; June–Aug.; Ingham; also Muskegon.

KIRCHNERIELLA OBESA (W. West) Schmidle. — Ditch; rare; July; Schoolcraft; also Schoolcraft (6).

Var. MAJOR (Bernard) G. M. Smith. — Monroe (5).

NEPHROCYTIUM AGARDHIANUM Näg. — Pools, streams, ditches, bogs and lake shores; frequent; May–Aug.; Branch, Cheboygan, Chippewa, Emmet, Monroe and Muskegon; also Schoolcraft (6) and Wayne (2).

NEPHROCYTIUM OBESUM West. — Pools and ditches; rare; July–Aug.; Emmet; also Schoolcraft (6).

OOCYSTIS BORGEI Snow. — Lakes, ditches, bogs and swamps; frequent; May–Oct.; Calhoun, Ingham, Livingston, Luce, Monroe, Muskegon and Ontonagon; also Monroe (5).

Oocystis crassa Wittr. — Lake shores, ditches and swamps; frequent; May–July; Berrien, Calhoun, Lapeer, Mackinac and Monroe; also Berrien (6).

Oocystis elliptica W. West. — Monroe (5) and Muskegon and Schoolcraft (6).

Oocystis eremosphaeria G. M. Smith. — Lake shores; rare; July–Aug.; Ingham.

Oocystis lacustris Chodat. — Beach pools and lake shores; occasional; July–Aug.; Houghton and Livingston.

Oocystis parva W. & G. S. West. — Lake shores, ditches and marsh pools; occasional; May–Aug.; Ingham and Newaygo.

Oocystis pusilla Hansg. — Ditches and rivers; occasional; Aug.–Oct.; Schoolcraft; also Monroe (5).

Oocystis solitaria Wittr. — Lake shores, bogs and swamps; frequent; May–Aug.; Chippewa, Ingham, Kalamazoo, Kent, Livingston, Luce and Newaygo.

Oocystis submarina Lagerh. — Lake shore; rare; June; Roscommon.

Quadrigula closterioides (Bohlin) Printz. — Berrien and Muskegon (6).

Quadrigula lacustris (Chodat) G. M. Smith. — Lake shore; occasional; Aug.; Cheboygan.

Quadrigula pfitzeri (Schröder) G. M. Smith. — Bog; rare; July; Chippewa.

Scenedesmus abundans (Kirchner) Chodat. — River; occasional; July; Cheboygan.

Scenedesmus acuminatus (Lagerh.) Chodat. — Ditch; rare; July; Ontonagon.

Scenedesmus arcuatus Lemm. — Water trough; occasional; July; Schoolcraft.

Var. platydisca G. M. Smith. — Lake shore; frequent; Aug.; Ingham.

Scenedesmus armatus (Chodat) G. M. Smith. — Lake; occasional; May; Kalamazoo.

Scenedesmus bernardii G. M. Smith. — Polluted water; occasional; Aug.; Emmet.

Scenedesmus bijuga (Turp.) Lagerh. — Lake shores, beach pools, swamp pools, bogs and ditches; abundant; May–Oct.; Baraga, Berrien, Cheboygan, Chippewa, Emmet, Lapeer, Manistique, Muskegon, Schoolcraft and Tuscola; also Monroe (5).

Var. ALTERNANS (Reinsch) Borge. — Monroe (5).

Var. FLEXUOSUS (Lemm.) Collins. — Monroe (5) and Berrien, Emmet and Schoolcraft (6).

SCENEDESMUS DENTICULATUS Lagerh. — Shallow streams, pools and lake shores; frequent; June–Aug.; Cheboygan; also Emmet (6).

SCENEDESMUS LONGUS Meyen. — Polluted beach pools; rare; July; Houghton.

SCENEDESMUS OBLIQUUS (Turp.) Kütz. — Lake shores, beach pools, rivers and bogs; common; May–Aug.; Berrien, Cheboygan, Emmet, Houghton, Kalamazoo and Lapeer; also Berrien and Emmet (6) and Wayne (2).

SCENEDESMUS QUADRICAUDA (Turp.) Bréb. — Lakes, rivers and pools; abundant; June–Aug.; Emmet, Houghton, Ingham, Iron, Lapeer, Mackinac, Monroe, Newaygo and Washtenaw; also Monroe (5) and Emmet, Muskegon and Schoolcraft (6).

Var. QUADRISPINA (Chodat) G. M. Smith. — Rivers and bogs; occasional; July–Aug.; Cheboygan and Iron.

Forma TYPICUS Kirchner. — Lake shore; rare; July; Cheboygan.

SELENASTRUM MINUTUM (Näg.) Collins. — Bog pool; occasional; July; Cheboygan.

SELENASTRUM WESTII G. M. Smith. — Monroe (5).

SORASTRUM BIDENTATUM Reinsch. — Lake shore; occasional; July; Emmet.

SORASTRUM SPINULOSUM Näg. — Lakes, rivers, beach pools and bogs; abundant; July–Oct.; Cheboygan, Emmet, Ingham, Monroe and Schoolcraft; also Monroe (5), Schoolcraft (6) and Wayne (2).

TETRAËDRON DUOSPINUM Ackley. — Small streams; rare; March; Monroe.

TETRAËDRON MINIMUM (A. Braun) Hansg. — Monroe (5).

TETRAËDRON MUTICUM (A. Braun) Hansg. — Ditches and rivers;

occasional; May–Oct.; Monroe, Ottawa and Schoolcraft; also Monroe (5).

TETRAËDRON PLANCTONICUM G. M. Smith. — Lake; rare; Aug.; Ingham.

TETRAËDRON QUADRATUM (Reinsch) Hansg. — Ditch; rare; July; Mackinac.

TETRAËDRON REGULARE Kütz. — Lake shore; occasional; Aug.; Ingham; also Monroe (5).

Var. TORSUM (Turner) Brunn. — Bog; rare; May; Newaygo.

TETRAËDRON RETICULATUM (Reinsch) Hansg. — Polluted pools; rare; Aug.; Emmet.

TETRAËDRON SIAMENSIS (W. & G. S. West) Wille. — Bog; occasional; Aug.; Cheboygan.

TETRAËDRON TRIGONUM (Näg.) Hansg. var. GRACILE Reinsch forma. — Bog pools, lakes and rivers; frequent; Aug.; Cheboygan.

TROCHISCIA ACICULIFERA (Lagerh.) Hansg. — Lake and ditch; occasional; April–Aug.; Cheboygan and Monroe.

TROCHISCIA ASPERA (Reinsch) Hansg. — Ditch; rare; April; Monroe.

TROCHISCIA GRANULATA (Reinsch) Hansg. — Lakes, bogs and swamps; frequent; April–Sept.; Branch, Cheboygan and Jackson.

TROCHISCIA HIRTA (Reinsch) Hansg. — Beach pools, bogs, marshes and swamps; abundant; May–Aug.; Emmet, Muskegon and Newaygo.

TROCHISCIA OBTUSA (Reinsch) Hansg. — Small stream; occasional; April; Branch.

TROCHISCIA RETICULARIS (Reinsch) Hansg. — Lake shores, bogs, swamps and pools; frequent; May–July; Chippewa, Houghton, Ionia, Muskegon and Newaygo.

ULOTRICHALES

ULOTRICHACEAE

BINUCLEARIA TATRANA Wittr. — Lake shores, bogs and swamps; frequent; May–July; Cheboygan, Livingston and Muskegon.

GEMINELLA INTERRUPTA Turpin. — Ditches and bogs; rare; July–Aug.; Cheboygan; also Berrien (6).

GEMINELLA ORDINATA (W. & G. S. West) Heering. — Ditch; occasional; July; Chippewa.

RADIOFILUM FLAVESCENS G. S. West. — Muskegon (6).

RADIOFILUM IRREGULARE (Wille) Brunn. — Lake shores, swamps and shallow streams; frequent; May–Aug.; Cheboygan, Kalamazoo and St. Clair; also Emmet (6).

STICHOCOCCUS BACILLARIS Näg. — Spring-fed pool; occasional; July; Cheboygan.

STICHOCOCCUS SCOPULINUS Hazen. — River; occasional; July; Houghton.

STICHOCOCCUS SUBTILIS (Kütz.) Klercker. — Bog pool; rare; Aug.; Cheboygan.

STICHOCOCCUS VARIABILIS W. & G. S. West. — Bog; occasional; Aug.; Cheboygan.

ULOTHRIX AEQUALIS Kütz. — Cold streams, springs, beach pools, lake shores, ponds and water trough; frequent; April–July; Cheboygan, Emmet, Jackson and Ontonagon.

ULOTHRIX MONILIFORMIS Kütz. — Cold ditches and springs; occasional; July; Chippewa and Ontonagon.

ULOTHRIX TENERRIMA Kütz. — Cold springs, pools and marshes; frequent; May–July; Allegan, Genesee, Mackinac, Shiawassee and Wayne.

ULOTHRIX TENUISSIMA Kütz. — Chippewa (6).

ULOTHRIX VARIABILIS Kütz. — Bogs, pools, springs and ditches; abundant; May–Aug.; Allegan, Baraga, Branch, Cheboygan, Chippewa, Delta, Houghton, Lenawee, Mackinac, Mecosta, Monroe, Newaygo, Shiawassee and Washtenaw.

ULOTHRIX ZONATA (Web. & Mohr) Kütz. — Cold streams, springs, rivers and ditches; frequent; April–Aug.; Cheboygan, Chippewa, Emmet, Houghton, Mackinac and Monroe; also Chippewa and Keweenaw (6).

MICROSPORACEAE

MICROSPORA AMOENA (Kütz.) Lagerh. — Allegan, Berrien and Muskegon (5).

MICROSPORA CRASSIOR (Hansg.) Hazen. — Ditches, lake shore, bogs, swamps and marshes; frequent; April–July; Branch, Houghton and Van Buren; also Allegan and Van Buren (6).

MICROSPORA FLOCCOSA (Vauch.) Thur. — Ditches and swamps; frequent; April; Branch and Hillsdale; also Wayne (2).

MICROSPORA LOEFGRENII (Nordst.) Lagerh. — River brinks and bogs; frequent; June–July; Manistique and St. Joseph.

MICROSPORA PACHYDERMA (Wille) Lagerh. — Found in practically all aquatic habitats studied; abundant; Feb.–Dec.; in all counties visited and probably in all others; also Berrien (6).

MICROSPORA QUADRATA Hazen. — Found in practically all aquatic habitats studied; abundant; May–Oct.; in most counties visited and probably in all others.

MICROSPORA STAGNORUM (Kütz.) Lagerh. — Streams, beach pools, ditches, bogs and swamps; abundant; April–Aug.; Cheboygan, Chippewa, Emmet, Houghton, Iron, Monroe and St. Joseph; also Keweenaw (6).

MICROSPORA TUMIDULA Hazen. — Ditches, cold streams, pools, bogs and marshes; abundant; April–Aug.; Branch, Cheboygan, Emmet, Houghton, Ingham, Lenawee, Monroe and Shiawassee.

MICROSPORA WILLEANA Lagerh. — Springs, lake shores, small streams and bog pools; frequent; May–Aug.; Branch, Cheboygan, Kent and Newaygo.

MICROSPORA WITTROCKII (Wille) Lagerh. — Spring-fed brook and cold stream; occasional; Aug.; Cheboygan, Emmet and Mecosta.

ULVACEAE

ENDODERMA POLYMORPHUM West. — Ditches and streams; rare; July; Gogebic and Schoolcraft.

CYLINDROCAPSACEAE

CYLINDROCAPSA GEMINELLA Wolle. — Ditches, swamps and bogs; occasional; July–Aug.; Allegan and Cheboygan; also Allegan and Van Buren (6).

Var. MINOR Hansg. — Lake shores, bogs and marshes; occasional; May–July; Cheboygan, Muskegon and Shiawassee.

PLEUROCOCCACEAE

PLEUROCOCCUS NAEGELII Chodat. — Bogs, ponds, cold stream and lake shore; abundant; April–Aug.; Calhoun, Cheboygan, Emmet, Houghton, Lapeer and Luce.

CHAETOPHORACEAE

CHAETOPELTIS AMERICANA (Snow) Collins. — "Michigan" (3).

CHAETOPHORA ELEGANS (Roth) Ag. — Lake shores, cold streams, beach pools and swamps; abundant in cold water; May–Aug.; Allegan, Cheboygan, Chippewa, Emmet, Menominee, Muskegon, Saginaw and Van Buren; also Allegan, Berrien, Chippewa, Schoolcraft and Van Buren (6) and Wayne (2).

CHAETOPHORA INCRASSATA (Hudson) Hazen. — Lake shores, creeks, ditches, marshes and bogs; abundant; April–Aug.; Baraga, Berrien, Cheboygan, Chippewa, Emmet, Ingham, Montcalm, Muskegon, Schoolcraft and Shiawassee; also Allegan, Berrien, Cheboygan, Chippewa, Emmet and Schoolcraft (6) and Wayne (2).

CHAETOPHORA PISIFORMIS (Roth) Ag. — Lake shores, ditches, cold streams and bogs; abundant; May–Aug.; Calhoun, Cheboygan, Clare, Emmet, Houghton, Ionia, Kalamazoo, Ontonagon, Sanilac and Shiawassee; also Wayne (2).

CHAETOSPHAERIDIUM GLOBOSUM (Nordst.) Klebahn. — Lake shores, ditches, swamps and bogs; frequent; May–Aug.; Branch, Cheboygan, Kent, Lapeer, Mecosta and Ontonagon.

CHAETOSPHAERIDIUM PRINGSHEIMII Klebahn. — Ditches, lakes, and swamps; occasional; May–July; Calhoun, Cheboygan and Schoolcraft.

DRAPARNALDIA ACUTA (Ag.) Kütz. — Cold stream; rare; July; Delta.

DRAPARNALDIA GLOMERATA (Vauch.) Ag. — Cold streams; frequent; April–Aug.; Cheboygan, Lenawee, Monroe and Shiawassee.

DRAPARNALDIA PLUMOSA (Vauch.) Ag. — Cold streams and lake shores; abundant; April–Aug.; Berrien, Branch, Cheboygan, Chippewa, Delta, Emmet, Hillsdale, Houghton, Lenawee, Luce, Monroe and Saginaw; also Berrien, Cheboygan, Emmet and Oakland (6).

MICROTHAMNION EXIGUUM Reinsch. — Mackinac and Schoolcraft (6).

STIGEOCLONIUM AESTIVALE (Hazen) Collins. — Lake shores and creeks; frequent; April–Aug.; Branch, Cheboygan, Delta and Emmet; also Houghton (6).

STIGEOCLONIUM AMOENUM Kütz. — Lake shores, ditches and streams; frequent; Allegan, Branch and Cheboygan; also Allegan and Cheboygan (6).

STIGEOCLONIUM ATTENUATUM (Hazen) Collins. — Lake shores, creeks and bog pools; frequent; June–Aug.; Baraga, Cheboygan, Chippewa, Houghton, Newaygo and St. Clair.

STIGEOCLONIUM GLOMERATUM (Hazen) Collins. — Cold brooks and bog pools; frequent; May–Aug.; Cheboygan, Emmet, Montcalm, Muskegon, Schoolcraft and St. Clair; also Allegan and Schoolcraft (6).

STIGEOCLONIUM LUBRICUM Kütz. — Lake shores and streams; occasional; July; Cheboygan and Houghton; also Houghton (6).

STIGEOCLONIUM NANUM Kütz. — Lake shore and marsh pools; frequent; April–July; Hillsdale, Lapeer, Mecosta and Ontonagon.

STIGEOCLONIUM STAGNATILE (Hazen) Collins. — Lake shores, bogs and ditches; frequent; April–Aug.; Cheboygan, Chippewa, Delta, Iron, Montcalm, Ontonagon, Saginaw, Shiawassee and Van Buren.

STIGEOCLONIUM SUBSECUNDUM Kütz. — Cold streams and ponds; rare; April; Branch, Cass and St. Joseph.

STIGEOCLONIUM TENUE (Ag.) Kütz. — Lake shores, ditches, cold streams, swamps and bogs; abundant; May–Aug.; Branch, Cass, Cheboygan, Ingham, Kalamazoo, Lenawee and Schoolcraft; also Emmet (6).

STIGEOCLONIUM VENTRICOSUM (Hazen) Collins. — Springs; occasional; July; Cheboygan.

APHANOCHAETACEAE

APHANOCHAETE REPENS A. Braun. — Lake shores, slow brooks, ditches, marshes and bogs; abundant; April–Aug.; Barry, Cheboygan, Chippewa, Delta, Houghton, Ingham, Jackson, Kent, Lapeer, Livingston, Marquette, Monroe, Oakland, Ottawa, Schoolcraft, Shiawassee and Van Buren; also Berrien, Cheboygan, Schoolcraft and Van Buren (6).

COLEOCHAETACEAE

COLEOCHAETE IRREGULARIS Pringsh. — Berrien (6).

COLEOCHAETE NITELLARUM Jost. — Muskegon (6).

COLEOCHAETE ORBICULARIS Pringsh. — Lake shore; frequent; Cheboygan, Chippewa, Kalamazoo, Livingston and Muskegon; also Wayne (2).

COLEOCHAETE PULVINATA A. Braun. — Lake shores; occasional; June–Aug.; Cheboygan, Lapeer and Washtenaw; also Chippewa (6) and Wayne (2).

COLEOCHAETE SCUTATA Bréb. — Lake shores; frequent; May–Aug.; Berrien, Cheboygan, Lapeer, Livingston and Luce; also Berrien and Schoolcraft (6) and Wayne (2).

COLEOCHAETE SOLUTA Pringsh. — Wayne (2).

TRENTEPOHLIACEAE

GONGROSIRA DEBARYANA Rabenh. — Bog pools; occasional; July; Cheboygan.

GONGROSIRA LACUSTRIS Brand. — Lake shore and river; occasional; July–Aug.; Cheboygan; also Crawford (6).

SIPHONOCLADIALES

CLADOPHORACEAE [1]

CHAETOMORPHA CHELONUM Collins. — Oakland (6) and "Michigan" (2).

CLADOPHORA CALLICOMA Kütz. — Lake shore; occasional; July–Aug.; Cheboygan and Emmet; also Emmet (6).

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[1] After Collins (3).

CLADOPHORA CRISPATA (Roth) Kütz. — Streams and beach pools; occasional; July–Aug.; Cheboygan and Oakland.

CLADOPHORA FLAVESCENS (Roth) Kütz. — Wayne (2).

CLADOPHORA FRACTA (Dillwyn) Kütz. — Berrien and Ottawa (6).

CLADOPHORA GLOMERATA (L.) Kütz. — Lake shores, rivers and bog pools; frequent to abundant; May–June; Berrien, Cheboygan and Emmet; also Berrien and Manistee (6), Wayne (8) and Wayne (2).

CLADOPHORA INSIGNIS (Ag.) Kütz. — Cold streams, shaded pools and lake shores; frequent; May–Nov.; Allegan, Delta, Kalamazoo and Monroe.

CLADOPHORA KUETZINGIANA Grun. — Cold brooks, lake shores and bog pools; frequent; April–Aug.; Emmet, Kalamazoo, Mackinac and Shiawassee.

CLADOPHORA NITIDA Kütz. — Small stream; rare; July; Houghton.

CLADOPHORA SECUNDA Kütz. — Beach pools, lake shores and streams; frequent; Calhoun, Genesee, Oakland, Sanilac, St. Clair and Wayne.

PITHOPHORA VARIA Wille. — Gratiot (6) and "Michigan" (3).

RHIZOCLONIUM CRASSIPELLITUM W. & G. S. West. — Ottawa (6).

Var. ROBUSTUM G. S. West. — River and margin of small stream; occasional; June; Shiawassee and Tuscola.

RHIZOCLONIUM CRISPUM Kütz. — Pools; abundant; June; St. Clair and Emmet.

RHIZOCLONIUM FONTANUM Kütz. — Bay; occasional; Aug.; Roscommon.

RHIZOCLONIUM HIEROGLYPHICUM (Ag.) Kütz. — Lake shore, rivers, ditches, streams, bogs and swamps; abundant; March–Nov.; present in all but two counties visited and probably in all counties; also Chippewa and Ottawa (6).

Var. HOSFORDII (Wolle) Collins. — Bay; rare; July; Menominee.

Var. MACROMERES Wittr. — Creeks, lakes and spring-fed pools; frequent; July–Aug.; Cheboygan and Otsego.

RHIZOCLONIUM HOOKERI Kütz. — Lake shore; rare; Aug.; Washtenaw.

SIPHONALES

VAUCHERIACEAE

DICHOTOMOSIPHON TUBEROSUS (A. Braun) Ernst. — Lake shores; common; June–Aug.; Cheboygan, Roscommon and Tuscola; also Oakland (6).

VAUCHERIA GEMINATA (Vauch.) De Candolle. — Streams, ditches, lakes, bogs and marshes; abundant; April–Aug.; Branch, Cass, Cheboygan, Emmet, Genesee, Gogebic, Ingham, Ionia, Kalamazoo, Luce, Mackinac, Montcalm, Muskegon and Washtenaw; also Cheboygan (6).

Var. DEPRESSA Transeau. — Shore of brooks; frequent; April–May; Berrien and Lenawee; also Berrien (6).

Forma RACEMOSA (Vauch.) Walz. — Slow streams and pools; locally common; April–July; Monroe; also Cheboygan and Van Buren (6).

VAUCHERIA LONGIPES Collins. — Ditch; occasional; May; Newaygo.

VAUCHERIA ORNITHOCEPHALA Ag. — Lake shores and pools; occasional; May–June; Allegan and Tuscola.

VAUCHERIA ORTHOCARPA Reinsch. — Berrien (6).

VAUCHERIA PACHYDERMA Walz. — Shaded swamps and streams; occasional; July–Aug.; Cheboygan; also Cheboygan (6).

VAUCHERIA POLYSPERMA Hass. — Brooks, beach pools and ditches; common; July–Aug.; Cheboygan, Chippewa and Mackinac.

VAUCHERIA SESSILIS (Vauch.) De Candolle. — Lake shores; beach pools, small streams and ponds; abundant; May–Aug.; in nearly every county visited and probably in all; also Cheboygan (6).

VAUCHERIA TERRESTRIS (Vauch.) De Candolle. — In and along cold streams; abundant; April–July; Chippewa, Emmet, Houghton, Jackson, Midland, Shiawassee and St. Clair.

STEPHANOKONTAE

OEDOGONIALES

OEDOGONIACEAE

BULBOCHAETE BREBISSONII Kütz. — Bog pools; occasional; July; Cheboygan.

BULBOCHAETE CRASSIUSCULA Nordst. — Lake shore; occasional; July–Aug.; Cheboygan; also Mackinac (6).

BULBOCHAETE CRENULATA Pringsh. — Lake shores; abundant; May–July; Chippewa; also Berrien (6).

BULBOCHAETE DISPAR Wittr. — Pond; rare; May; Livingston.

BULBOCHAETE GIGANTEA Pringsh. — Bog pools; occasional; July; Cheboygan.

BULBOCHAETE INSIGNIS Pringsh. — Berrien (6).

BULBOCHAETE INTERMEDIA De Bary. — Lake shores, ditches and bogs; occasional; July–Aug.; Cheboygan and Schoolcraft.

BULBOCHAETE MIRABILIS Wittr. — Lake shores and bog pools; occasional; July–Aug.; Cheboygan.

Forma IMMERSA (Wittr.) Hirn. — Swamps; rare; May; Muskegon.

BULBOCHAETE OBLIQUA Lund. — Lake shores and bog pools; rare; July–Aug.; Cheboygan.

BULBOCHAETE RECTANGULARIS Wittr. — Ditch; rare; May–July; Schoolcraft; also Berrien (6).

Var. HILOENSIS Nordst. — Cold stream and ditch; occasional; July; Chippewa and Mackinac.

BULBOCHAETE TENUIS (Wittr.) Hirn. — Lake shore; rare; July; Chippewa.

BULBOCHAETE VALIDA Wittr. — Bog pools; rare; July; Cheboygan.

BULBOCHAETE VARIANS Wittr. — Lake shores; frequent; May–Aug.; Berrien, Lapeer and Washtenaw; also Berrien (6).

Var. SUBSIMPLEX (Wittr.) Hirn. — Lake shores; rare; June–Aug.; Lapeer and Washtenaw.

OEDOGONIUM ACROSPORUM De Bary. — Ponds, pools and bogs; frequent; July–Aug.; Cheboygan; also Berrien and Schoolcraft (6).

Var. BATHMIDOSPORUM (Nordst.) Hirn. — Lake shore; frequent; May; Kalamazoo.

Var. MAJUSCULUM Nordst. — Lake shore; rare; May; Muskegon.

OEDOGONIUM AMERICANUM Transeau. — Margins of streams and lakes; occasional; May–Aug.; Cheboygan, Gogebic and Newaygo; also Berrien (6).

OEDOGONIUM ARGENTEUM Hirn. — Swamps; rare; July; Houghton.

OEDOGONIUM BORISIANUM (Le Cl.) Wittr. — Lake shores, beach pools and bogs; frequent; May–Aug.; Cheboygan and Schoolcraft; also Berrien (6).

OEDOGONIUM BRAUNII Kütz.; Pringsh. — Pools, swamps and oxbows; frequent; May–Sept.; Cheboygan, Chippewa, Jackson, Kent and Ottawa; also Schoolcraft (6).

OEDOGONIUM CAPILLARE (L.) Kütz. — Wayne (2).

OEDOGONIUM CAPILLIFORME Kütz.; Wittr. — Dam at fish hatchery; abundant; July; Gogebic.

Var. DEBARYANUM (Chmiel.) Hirn. — Small streams and ditches; rare; June–July; Gogebic and Tuscola.

OEDOGONIUM CARDIACUM (Hass.) Wittr. — Lake shores, ditches, pools and bogs; occasional; May–July; Emmet, Houghton, Muskegon and Ontonagon.

Forma INTERJECTUM Hirn. — Swamp pool; rare; July; Houghton.

OEDOGONIUM CILIATUM (Hass.) Pringsh. — River; rare; May; Ottawa.

OEDOGONIUM CONCATENATUM (Hass.) Wittr. — Lake shore; rare; May; Kalamazoo; also Berrien (6).

OEDOGONIUM CRASSIUSCULUM Wittr. — Lake shore; occasional; May; Muskegon.

Var. IDIOANDROSPORUM Nordst. & Wittr. — Lake shores, slow streams, swamps and bogs; frequent; May–Sept.; Cheboygan, Houghton, Muskegon, Oakland, St. Clair and Wayne.

OEDOGONIUM CRASSUM (Hass.) Wittr. — Berrien and Schoolcraft (6).

Var. AMPLUM (Magnus & Wille) Hirn. — Bog and beach pools; frequent; July–Aug.; Cheboygan.

OEDOGONIUM CRENULATOCOSTATUM Wittr. — Lake shores; frequent; July–Aug.; Cheboygan; also Emmet (6).

Var. LONGIARTICULATUM Hansg. — Lake shore; occasional; Aug.; Cheboygan.

OEDOGONIUM CRISPUM (Hass.) Wittr. — Small streams, bogs and ponds; frequent; May–July; Berrien, Cheboygan, Chippewa and Luce; also Berrien (6).

Var. GRACILESCENS Wittr. — Bog pools; frequent; May; Barry.

Forma INFLATUM Hirn. — Berrien (6).

OEDOGONIUM CRYPTOPORUM Wittr. var. VULGARE Wittr. — Berrien (6).

OEDOGONIUM CURTUM Wittr. & Lund. — Swamps; rare; April; Branch and Monroe.

OEDOGONIUM CYATHIGERUM Wittr. — Allegan (6).

OEDOGONIUM DECIPIENS Wittr. — Bog pools; locally common; July; Cheboygan.

Forma DISSIMILE Hirn. — Bog pools; rare; July; Cheboygan.

OEDOGONIUM DEPRESSUM Pringsh. — Wayne (2).

OEDOGONIUM ECHINOSPERMUM A. Braun. — Lake shores, swamps, cold pools and rarely in bogs; frequent; May–Aug.; Cheboygan, Genesee, Montcalm and Muskegon.

OEDOGONIUM FRAGILE Wittr. — Marsh pools, rarely in bogs; frequent; April; Branch and St. Joseph; also Berrien (6).

OEDOGONIUM GALLICUM Hirn. — Lake shores, streams, ditches, swamps and bogs; frequent; May–July; Barry, Chippewa, Ionia, Lapeer, Muskegon and Sanilac.

OEDOGONIUM GLOBOSUM Nordst. — Bog pools; rare; July; Chippewa.

OEDOGONIUM GRACILLIMUM Wittr. & Lund. — Bog pools; frequent; May–July; Cheboygan; also Berrien (6).

OEDOGONIUM GRANDE Kütz.; Wittr. — Slow streams, rivers and ponds; frequent; May–July; Allegan, Berrien, Gogebic and Oakland; also Allegan and Berrien (6).

Var. ANGUSTUM Hirn. — Van Buren (6).

Var. MAJUS Hansg. — Margins of river and bogs; occasional; May–July; Allegan and Cheboygan.

OEDOGONIUM HISPIDUM Nordst. — Bog pools; rare; May; Livingston.

OEDOGONIUM HYSTRICINUM Transeau & Tiffany. — Slow streams and ditches; frequent; June–July; Chippewa and Schoolcraft.

OEDOGONIUM IRREGULARE Wittr. — Margins of streams; frequent; May–June; Ottawa; also Allegan (6).

Var. CONDENSATUM (Hallas) Hirn. — Lake shore; rare; July; Chippewa.

OEDOGONIUM LAEVE Wittr. — Allegan (6).

OEDOGONIUM LANDSBOROUGHI (Hass.) Wittr. — Lake shore; occasional; Aug.; Cheboygan.

OEDOGONIUM LAUTUMNIARUM Wittr. — Rapid stream; rare; July; Houghton.

OEDOGONIUM LONGATUM Kütz. — Slow streams and ditches; occasional; June; St. Clair.

OEDOGONIUM MACRANDRIUM Wittr. — Margin of river; occasional; May; Allegan.

Forma AEMULANS Hirn. — Margin of river; locally common; May; Ottawa.

Var. HOHENACKERII (Wittr.) Tiffany. — Ditch; occasional; May; Muskegon.

Var. PROPINQUUM (Wittr.) Hirn. — Ditch; rare; May; Ottawa.

Var. SCROBICULATUM Ackley. — River margin; frequent; May; Ottawa.

OEDOGONIUM MACROSPERMUM W. & G. S. West. — Bog; rare; July; Cheboygan.

OEDOGONIUM MAGNUSII Wittr. — Bog pools; occasional; Aug.; Cheboygan.

OEDOGONIUM MEGAPORUM Wittr. — Bog pools; occasional; July; Cheboygan.

OEDOGONIUM MEXICANUM Wittr. — Lake shore; abundant; May; Muskegon.

OEDOGONIUM MICHIGANENSE Tiffany. — Bog pools; occasional; July–Aug.; Cheboygan.

Oedogonium minus Wittr. — Bog pools; frequent; July; Cheboygan.

Oedogonium monile Berk. & Harv.; Wittr. — Bog pools; occasional; July; Cheboygan.

Oedogonium moniliforme Wittr. — Margins of small lake and river; occasional; May; Muskegon and Ottawa.

Oedogonium multisporum Wood var. magnum Ackley. — Lake shore; locally common; May; Muskegon.

Oedogonium nodulosum Wittr. — Lake shores, ditches and swamps; frequent; May–April; Kalamazoo and Monroe.

Var. commune Hirn. — Ponds; abundant; April; Monroe.

Oedogonium oblongum Wittr. — Swamp pools; rare; June; Lapeer.

Forma majus (Nordst.) Hirn. — Bog pools; occasional; July; Cheboygan.

Oedogonium oelandicum Wittr.; Hirn. — Bog pools; rare; July; Cheboygan.

Oedogonium pachydermum Wittr. & Lund. — Ponds and small streams; rare; April–July; Chippewa and Monroe.

Oedogonium paludosum (Hass.) Wittr. — Swamp pools; occasional; May–June; Genesee; also Wayne (2).

Var. parvisporum Hirn. — Ditches; rare; May–June; Berrien and Ionia; also Berrien (6).

Oedogonium pratense Transeau. — Ditches, bogs, swamps and beach pools; frequent; July–Aug.; Cheboygan and Mackinac; also Emmet (6).

Oedogonium princeps (Hass.) Wittr. — Polluted pond; rare; June; St. Clair.

Oedogonium pringsheimii Cramer; Wittr. — Lake shores, swamps and slow streams; frequent; May–Aug.; Calhoun, Cheboygan, Ingham, Ionia, Kalamazoo and Wayne.

Var. nordstedtii Wittr. — Lake shores, ditches and bog pools; occasional; May–Aug.; Cheboygan, Kentand Newaygo.

Oedogonium punctatostriatum De Bary. — Lake shore; occasional; Aug.; Cheboygan.

Oedogonium reinschii Roy. — Bog pools; rare; July; Cheboygan.

Oedogonium richterianum Lemm. — Swamp pools; rare; June; Lapeer.

Oedogonium rufescens Wittr. — Polluted stream, water trough and gravel pit; frequent; May–July; Lapeer, St. Clair and Tuscola; also Allegan and Berrien (6).

Var. exiguum (Elfv.) Tiffany. — Swamp; abundant; May; Muskegon.

Oedogonium rugulosum Nordst. — Berrien (6).

Oedogonium sancti thomae Wittr. & Cleve. — Lake shore; rare; June; Lapeer.

Oedogonium sexangulare Cleve. — Lake shore and bog pools; frequent; July–Aug.; Cheboygan.

Oedogonium sodiroanum Lagerh. — Swamp pool; rare; May; Mecosta.

Oedogonium suecicum Wittr. — River brink; rare; May; Ottawa.

Oedogonium taphrosporum Nordst. & Hirn. — Bog pools; occasional; July; Cheboygan.

Oedogonium tiffanii Ackley. — Lake shore; frequent; May; Muskegon.

Oedogonium undulatum (Bréb.) A. Braun; Wittr. — Lake shore and ponds; rare; July; Cheboygan; also Chippewa (6).

Var. americanum Transeau. — Chippewa (6).

Oedogonium upsaliense Wittr. — Lakes, rivers, ponds and bogs; frequent; April–May; Kalamazoo, Livingston, Monroe and Ottawa; also "Michigan" (3).

Oedogonium varians Wittr. & Lund. — Lake shores and ponds; occasional; April–Sept.; Jackson and Monroe.

Oedogonium vaucherii (Le Cl.) A. Braun.; Wittr. — Bog; rare; July; Cheboygan.

Oedogonium verrucosum Hallas. — Bog pools; rare; July–Aug.; Cheboygan.

AKONTAE

ZYGNEMALES

ZYGNEMACEAE

DEBARYA AMERICANA Transeau. — Beach pool; occasional; Aug.; Emmet.

DEBARYA CRUCIATA Price. — Beach pools; abundant; July; Schoolcraft.

DEBARYA DECUSSATA Transeau. — Beach pools; frequent; July–Aug.; Cheboygan and Emmet; also Chippewa (6).

DEBARYA GLYPTOSPERMA (De Bary) Wittr. — Lake shores and swamp pools; frequent; May–Aug.; Emmet and Muskegon.

DEBARYA LAEVIS (Kütz.) W. & G. S. West. — Lake shore; occasional; July; Cheboygan.

MOUGEOTIA AMERICANA Transeau. Lake shore; rare; Aug.; Cheboygan.

MOUGEOTIA CALCAREA (Cleve) Wittr. — Lake shores and streams; frequent; May–Aug.; Cheboygan and Muskegon; also Emmet (6).

Var. BICALYPTRATA (Wittr.) Transeau. — Emmet (6).

MOUGEOTIA CYANEA Transeau. — Shallow pools; occasional; July; Cheboygan and Luce.

MOUGEOTIA ELEGANTULA Wittr. — Lake shore; rare; Aug.; Cheboygan; also Muskegon (6).

MOUGEOTIA GENUFLEXA (Dillwyn) Ag. — Lake shores, beach pools and creeks; common; July–Aug.; Cheboygan, Emmet, Livingston, Ontonagon and Osceola; also Wayne (8).

Var. GRACILIS Reinsch. — Lakes, beach pools and shallow ponds; occasional; June–July; Cheboygan and Oakland.

MOUGEOTIA GRACILLIMA (Hass.) Wittr. — Muskegon (6).

MOUGEOTIA LAETEVIRENS (A. Braun) Wittr. — Bog pools; rare; July; Cheboygan.

MOUGEOTIA PARVULA Hass. — Lake shores, beach pools and streams; frequent; May–July; Cheboygan and Kent; also Berrien (6).

MOUGEOTIA QUADRANGULATA Hass. — Allegan and Cheboygan (6).

MOUGEOTIA RECURVA (Hass.) De Toni. — Lake shores and slow stream; frequent; June–Aug.; Cheboygan, St. Clair and Washtenaw.

MOUGEOTIA ROBUSTA (De Bary) Wittr. — Bog pools and slow streams; occasional; July; Cheboygan and Delta.

Var. BIORNATA Wittr. — Berrien (6).

MOUGEOTIA SCALARIS Hass. — Lake shores, beach pools and slow streams; frequent; June–Nov.; Cheboygan, Emmet, Luce, Monroe and Saginaw; also Wayne (2).

MOUGEOTIA SPHAEROCARPA Wolle. — Lake shores, beach pools and slow streams; frequent; July–Aug.; Cheboygan and Emmet.

MOUGEOTIA VIRIDIS (Kütz.) Wittr. — Lake shores, beach pools, streams and cold pool; frequent; May–Aug.; Cheboygan, Emmet and Kent; also Allegan (6) and Wayne (2).

MOUGEOTIOPSIS CALOSPORA Palla. — Ditch; rare; July; Schoolcraft.

SPIROGYRA AFFINIS (Hass.) Petit. — Slow streams; abundant; June; Sanilac and St. Clair; also Allegan (6).

SPIROGYRA BORGEANA Transeau. — Creek; occasional; Aug.; Cheboygan.

SPIROGYRA BORYSTHENICA Kasan. & Smirn. — Swamps, ponds and ditches; frequent; May–June; Genesee, Ionia and Mecosta.

SPIROGYRA CATENAEFORMIS (Hass.) Kütz. — Bog pools; rare; July; Cheboygan.

SPIROGYRA CIRCUMLINEATA Transeau. — Lake shore; occasional; July; Cheboygan and Emmet.

SPIROGYRA COMMUNIS (Hass.) Kütz. — Margin of rivers, swamps and ditches; frequent; May–Sept.; Clinton and Ionia.

SPIROGYRA CONDENSATA (Vauch.) Kütz. — Ditches; frequent; May–June; Ionia, Shiawassee and Wayne.

SPIROGYRA CRASSA Kütz. — Ditch; rare; June; Tuscola; also Wayne (2).

SPIROGYRA DECIMINA (Müll.) Kütz. — Lake shores and ditches; occasional; June–Aug.; Cheboygan and Sanilac.

Var. CRASSIOR Gutwinski. — Ditch; rare; June; Sanilac.

Var. TRIPLICATA Collins. — Swamp pools and shallow creeks; rare; May–July; Chippewa and Newaygo.

SPIROGYRA DUBIA Kütz. — Allegan and Oakland (6).

SPIROGYRA ELLIPSOSPORA Transeau. — Allegan and Macomb (6).

SPIROGYRA FALLAX (Hansg.) Wille. — Swamp pools; frequent; June; Genesee.

SPIROGYRA FARLOWII Transeau. — Ditches, bogs, creeks and marshes; frequent; May–July; Cheboygan, Ingham, Livingston, Luce, Newaygo and Tuscola.

SPIROGYRA FLAVESCENS (Hass.) Kütz. — Wayne (2).

SPIROGYRA FLUVIATILIS Hilse. — Lake shores and beach pools; rare; Aug.; Cheboygan and Emmet; also Allegan and Chippewa (6).

SPIROGYRA GRACILIS (Hass.) Kütz. — Pools; occasional; July; Emmet; also "Michigan" (3).

SPIROGYRA GREVILLEANA (Hass.) Kütz. — Bog pools and brooks; rare; April–July; Cheboygan and Jackson.

SPIROGYRA INCONSTANS Collins. — Ditches and shallow pools; occasional; July; Luce.

SPIROGYRA INFLATA (Vauch.) Rabenh. — Brooks, ditches, swamps and bogs; frequent; May–July; Cheboygan, Jackson, Livingston and Luce.

SPIROGYRA JUERGENSII Kütz. — Lake shores and bogs; frequent; May–July; Calhoun, Emmet and Mecosta.

SPIROGYRA JUGALIS (Fl. Dan.) Kütz. — Chippewa (6).

SPIROGYRA LAXA Kütz. — Ditches, marshes, swamps and bogs; frequent; May–July; Cheboygan, Chippewa, Houghton, Luce, Mecosta and Wayne.

SPIROGYRA LONGATA (Vauch.) Kütz. — Lake shores, slow streams, ditches, ponds and bogs; frequent; May–Nov.; Cheboygan, Gogebic, Ionia, Montcalm, Washtenaw and Wayne; also Wayne (2).

SPIROGYRA MAJUSCULA Kütz. — Lake shores, slow streams and rivers; frequent; May–Aug.; Berrien, Cheboygan, Delta, Emmet, Ottawa, Sanilac and St. Clair; also Van Buren (6).

SPIROGYRA MAXIMA (Hass.) Wittr. — Iosco (6), SPIROGYRA MIRABILIS (Hass.) Kütz.; Ackley. — Beach pool; rare; July; Ontonagon.

SPIROGYRA NITIDA (Dillwyn) Link. — Macomb (6).

SPIROGYRA NOVAE-ANGLIAE Transeau. — Bog; occasional; July–Aug.; Cheboygan.

SPIROGYRA PORTICALIS (Müll.) Cleve. — Ditches and swamp pools; frequent; May–April; Barry, Montcalm and Wayne.

SPIROGYRA PRATENSIS Transeau. — Bog pools; occasional; July; Cheboygan.

SPIROGYRA PROTECTA Wood. — Ditches, creeks, ponds and pools; frequent; May–July; Allegan, Cheboygan, Chippewa, Montcalm, Oakland, Ottawa and Wayne; also Van Buren (6) and "Michigan" (3).

SPIROGYRA REFLEXA Transeau. — Lake shores and pools; occasional; July; Cheboygan; also Berrien (6).

SPIROGYRA RIVULARIS (Hass.) Rabenh. — Ditch; rare; June; Ionia.

SPIROGYRA SINGULARIS Nordst. — Lake shores, ditches and bogs; frequent; June–July; Chippewa, Gogebic, Ionia, Mackinac and Mecosta.

SPIROGYRA SPREEIANA Rabenh. — Pools; occasional; Aug.; Emmet.

SPIROGYRA TENUISSIMA (Hass.) Kütz. — Ditches and beach pools; frequent; May–June; Berrien, Chippewa, Kent, Lapeer and Mackinac; also Berrien (6).

SPIROGYRA VARIANS (Hass.) Kütz. — Slow streams, ditches, swamps, lake shores, bogs and pools; abundant; May–Aug.; found in most counties and probably present in all; also Berrien, Cheboygan, Ottawa and Schoolcraft (6).

Var. GRACILIS Borge. — Slow streams, ditches and ponds; frequent; May–July; Houghton and Wayne.

Var. MINOR Teodoresco. — Lake shores, beach pools, ditches and swamps; frequent; May–Sept.; Calhoun, Emmet, Ingham, Jackson, Kent, Shiawassee and Wayne.

Var. SCROBICULATA Stockmayer. — Pools and bogs; occasional; Cheboygan and Wayne.

SPIROGYRA WEBERI Kütz. — Cold streams, ditches and ponds;

frequent; Baraga, Cheboygan, Kent, Oakland, Saginaw, Shiawassee and Wayne.

ZYGNEMA CHALYBEOSPERMUM Hansg. — Lake shore; occasional; Sept.; Jackson.

ZYGNEMA CYANOSPORUM Cleve. — Creeks, ditches, lake shores and pools; occasional; July–Aug.; Cheboygan and Mackinac; also Emmet and Schoolcraft (6).

ZYGNEMA DECUSSATUM (Vauch.) Transeau. — Beach pools; occasional; July–Aug.; Emmet and Mackinac.

ZYGNEMA INSIGNE (Hass.) Kütz. — Slow streams, ditches and swamp pools; frequent; April–July; Houghton, Ionia, Monroe and St. Joseph; also Wayne (2).

ZYGNEMA LEIOSPERMUM De Bary. — Ditch; rare; April; Monroe.

ZYGNEMA PECTINATUM (Vauch.) Ag. var. CONSPICUUM (Hass.) Kirchner. — Lake shore; occasional; May; Kalamazoo.

ZYGNEMA STELLINUM (Vauch.) Ag. — Wayne (2).

ZYGOGONIUM ERICETORUM (Kütz.) Hansg. — Lake shores and beach pools; occasional; Emmet and Mackinac; also Wayne (2).

EUGLENINEAE

EUGLENACEAE

EUGLENA ACUS Ehrenb. — Lake shore; abundant; July; Houghton.

EUGLENA PROXIMA Dangeard. — Slow stream; abundant; May; Wayne.

EUGLENA SPIROGYRA Ehrenb. — Ditch, swamp pools and small pond; frequent; April–July; Delta, Kalamazoo, Monroe and Wayne; also Monroe (5).

PHACUS LONGICAUDA (Ehrenb.) Duj. — Marsh pools; frequent; May; Kalamazoo and Monroe; also Monroe (5).

PHACUS PLEURONECTES (O. F. M.) Duj. — Swamp and lake shores; frequent; May; Barry and Kalamazoo.

PERIDINIEAE

GYMNODINIACEAE

GLENODINIUM PULVISCULUS (Ehrenb.) Stein. — Bog pool and pond in limestone quarry; occasional; July; Newaygo and Schoolcraft.

GLENODINIUM ULIGINOSUM Schilling. — Swamp pools; abundant; May; Muskegon.

GYMNODINIUM AERUGINOSUM Stein. — Swamp pools; rare; May; Muskegon.

PERIDINIACEAE

CERATIUM HIRUNDINELLA O. F. M. — Lake shores; frequent; Aug.–Sept.; Ingham, Jackson and Washtenaw.

PERIDINIUM ANGLICUM G. S. West. — Swamp pools; rare; May; Calhoun.

PERIDINIUM CINCTUM Ehrenb. — Ditches; rare; July; Ontonagon.
Var. LEMMERMANNI G. S. West. — Marshes, bogs and swamps; frequent; May; Kalamazoo, Muskegon and Newaygo.

COLLEGE OF THE CITY OF DETROIT
DETROIT, MICHIGAN

INDEX TO GENERA

PAGE
Actinastrum 24
Anabaena 11
Ankistrodesmus 24
Aphanizomenon 12
Aphanocapsa 4
Aphanochaete 33
Aphanothece 4
Apiocystis 20
Asterococcus 20
Batrachospermum 17
Binuclearia 28
Botryococcus 17
Bulbochaete 36
Calothrix 15
Ceratium 47
Chaetomorpha 33
Chaetopeltis 31
Chaetophora 31
Chaetosphaeridium 31
Chamaesiphon 8
Characiopsis 18
Characium 22
Chlamydomonas 20
Chlorella 24
Chlorobotrys 17
Chlorococcum 23
Chroococcus 4
Cladophora 33
Coelastrum 24
Coelosphaerium 5
Coleochaete 33
Crucigenia 25
Cylindrocapsa 30
Cylindrospermum 12
Dactylococcopsis 6
Dasygloea 8
Debarya 42
Dichothrix 15
Dichotomosiphon 35
Dictyosphaerium 23

PAGE
Dimorphococcus 24
Dinobryon 17
Draparnaldia 31
Endoderma 30
Eremosphaera 23
Eudorina 19
Euglena 46
Excentrosphaera 25
Geminella 29
Glenodinium 47
Gloeocapsa 6
Gloeocystis 20
Gloeocystopsis 21
Gloeotaenium 25
Gloeothece 6
Gloeotrichia 15
Gomphosphaeria 6
Gongrosira 33
Gonium 19
Gymnodinium 47
Hapalosiphon 16
Hydrodictyon 21
Kirchneriella 25
Lyngbya 8
Merismopedia 6
Microchaete 14
Microcoleus 9
Microcystis 7
Microspora 29
Microthamnion 32
Mougeotia 42
Mougeotiopsis 43
Nephrocytium 25
Nodularia 13
Nostoc 13
Oedogonium 36
Oocystis 25
Ophiocytium 18
Oscillatoria 9
Palmodictyon 21

PAGE
Pandorina.................. ... 20
Pediastrum................ ... 21
Peridinium.... 47
Phacus........................ 46
Phormidium.......... 11
Pithophora 34
Planktosphaeria.............. 21
Pleurococcus............ ... 31
Quadrigula......... 26
Radiofilum................ ... 29
Rhizoclonium................ 34
Rivularia...................... 16
Scenedesmus................. 26
Schizochlamys................ 21
Schizothrix.................... 11
Scytonema.................. 14
Selenastrum.................. 27
Sorastrum.................... 27
Sphaerocystis................. 21

PAGE
Spirogyra...................... 43
Spirulina...................... 11
Stichococcus.................. 29
Stigeoclonium................ 32
Stigonema.................... 16
Synechocystis................. 8
Synura 16
Tetraëdron.................... 27
Tetraspora..... 21
Tolypothrix.................... 14
Tribonema..................... 19
Trochiscia..................... 28
Ulothrix....................... 29
Vaucheria..................... 35
Volvox........................ 20
Westella...................... 24
Xenococcus... 8
Zygnema..................... 46
Zygogonium.................. 46

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MICROFOSSILS FROM GREENLAND COAL *

CHESTER A. ARNOLD

THIS account embodies the result of a study of some forty samples of coal which were secured by Mr. Carl O. Erlanson along the west coast of Greenland during the summer of 1928. The investigation was started by Mr. Erlanson himself, but his appointment to another position made it necessary for him to discontinue the study. The material was then submitted to the present author for examination and report. Not having the advantage of an intimate knowledge of the places where the material was found, he must omit many details pertaining to its occurrence, since the only sources of such information consisted of Mr. Erlanson's notes and the various publications which deal with the fossil flora and the geology of the region. The time allotted to the present investigation was too short to permit identification of many of the plant remains, but it is hoped that further studies of the material will yield data for additional reports.

LOCALITIES

The collections were made along the southeast coast of the Nugsuaks Peninsula and along the eastern coast of Disko Island, which is separated from the peninsula by the Vaigat. The localities ranged from the Atâ Delta on the Nugsuaks Peninsula at approximately 70 degrees 15 minutes north to Marrak on the southeast coast of Disko Island, which is approximately at 69 degrees 20 minutes north latitude (Map 1).

Some forty samples were collected at ten different localities. The data for each collection, as taken from Mr. Erlanson's notes, are given below.

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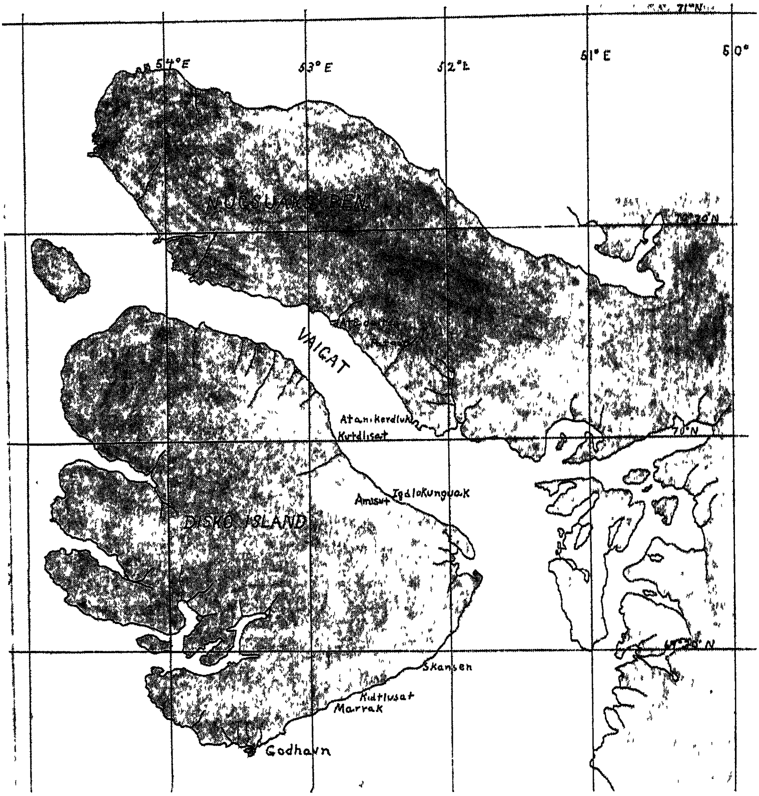
* Papers from the Department of Botany, University of Michigan, No. 357.



MAP 1. Nugsuaks Peninsula and Disko Island, west coast of Greenland, showing localities where coal was collected. Modified from a Danish government map, Copenhagen, 1888. Scale 1:750,000

1. *South coast of the Nugsuaks Peninsula*

1. *Atâ Delta.* — A, one mile southeast of the delta at altitude of 250 meters, sandstone above and below; B, same as for A, but at 150 meters, sandstone above and below; C, two miles southeast of delta, at 168 meters, sandstone above and below (3 collections); D, northwest side of delta at 70 meters.

2. *Patoot.* — A, at altitude of 85 meters; B, at 165 meters

(2 collections); C, between 200 and 300 meters; D, at 255 meters; E, at 350 meters; F, at 380 meters.

3. *Atanikerdluk.* — A, just south of the peninsula near tide level (Steenstrup's station No. 4[1]); B, at outer extremity of peninsula at tide level (Steenstrup's station No. 1[1]).

2. *East coast of Disko Island*

4. *Kutdlisat.* — At mine, at altitude of 20 meters.

5. *Igdlokunguak.* — One collection between here and Amisut, along stream at altitude of 30 meters.

6. *Amisut.* — A, at sea level (2 collections); B, at altitude of 1 meter; C, at 6 meters; D, north side at 10 meters; E, another collection with no data.

7. *Skansen.* — A, two miles inland at altitude of 140 meters; B, same as for A, but at 385 meters; C, same as for A, but at 420 meters; D, one and one-half miles west and one and one-half miles inland, at 70 meters; E, same as for D, but at 150 meters; F, one mile inland, at 175 meters; G, 400 meters inland, at 8 meters; H, one-half mile east, at 5 meters; I, one-quarter mile west in stream bed; J, another collection at 270 meters, but no additional data.

8. *Kidtlusat.* — One collection at altitude of 90 meters.

9. *Marrak.* — One collection at altitude of 3 meters.

10. *Evinasugsuit.* — One collection; altitude not given. This station is between Skansen and Godhavn, but the exact location is not given.

THE COAL-BEARING FORMATIONS

The geological age of the coal under consideration is upper Cretaceous and Tertiary. Oswald Heer's studies of the fossil plants of Greenland led him to recognize four floras, namely: the Kome, or lower Cretaceous, the Atâne and the Patoot of the upper Cretaceous, and the Tertiary, which he considered to be Miocene.[2] Other geologists have expressed the opinion that the Tertiary flora is Eocene instead of Miocene, and Seward,[3] the most recent paleobotanist to examine the rocks of west Greenland, believes that further subdivisions of the flora should be made. Since Mr. Erlanson made no collections in the Kome series it will not be considered further in this account.

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[1] Steenstrup, K. J. V., "Über die Lagerungsverhältnisse der Kohlen und Versteinerungen führenden Bildungen auf der Westküste von Grønland," *Flora Fossilis Arctica,* 7: 228–250. Zurich, 1883.

The Atâne flora is the most widespread and it is probable that the majority of the coal collections belong to this. The Patoot flora is higher than the Atâne and is known at the place called Patoot. At this place it commences at about the 500-foot level and goes upward to 2,000 feet. Therefore, all the collections made at Patoot, with the exception of the lowest one at 85 meters, belong to the Patoot series.

In general the Tertiary beds are at a high level.[4] At Atanikerdluk they appear between 1,100 and 1,200 feet above sea level and continue upward for about 2,000 feet more. At Patoot the Cretaceous beds go up to 2,600 feet, where they are overlain by the Tertiary. At Atâ the Tertiary beds extend from 2,180 to 3,180 feet above tide. At no place, then, on the Nugsuaks Peninsula were any of the collections taken from a level high enough to be included in the Tertiary.

At many places on Disko Island the Cretaceous-Tertiary boundary has not been determined. At Skansen Seward examined Cretaceous strata as high up as 1,900 feet. Since the highest collection made at this place was approximately at 1,800 feet, it is altogether improbable that any of the material from Skansen is Tertiary. At the other localities on Disko Island there appears to be no record of the lower limit of the Tertiary, but since all the collections were made at low levels their Cretaceous age is probable.

The greater part of the coal-bearing formation of this part of Greenland consists of loose sand or soft to hard sandstone.

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[2] Heer, Oswald, "Die fossile Flora Grönlands," *Flora Fossilis Arctica,* 6 (2) and 7. Zurich, 1882–83.

[3] Seward, A. C., "The Cretaceous Plant-bearing Rocks of Western Greenland, *Phil. Trans. Roy. Soc. London. B,* 215 : 57–174. 1926.

[4] White, David, and Schuchert, C., "Cretaceous Series of the West Coast of Greenland," *Bull. U. S. Geol. Surv.,* 9 : 334. 1898.

Almost anywhere throughout this sand formation where large portions are exposed there are layers of coal varying in thickness from very thin layers to beds three or four feet thick. Above and below the coal there is usually a layer of shale, but occasionally the shale is on one side only, with the sandstone on the other, or, in other places, there may be sandstone on both sides, the shale not being present. Besides the coal carbonized tree trunks are often found lying horizontal and parallel to the sand layers, but sometimes they stand upright, as they grew.[5]

The thickness of the coal formation is difficult to determine, since the entire horizon is rarely exposed. At only one place (Sarkak, which is southeast of Atanikerdluk) can the lower limit be seen lying on the basal gneiss. At other places it dips below the sea or rests upon basalt intrusions. The upper limit varies from sea level to 2,000 feet. Most of the layers lie horizontal, but in some there is a dip of 10 to 15 degrees, and, rarely, as much as 40 degrees. The direction of the dip varies according to local disturbances.

Coal has been known in Greenland as long as Greenland itself has been known. Mention is made of it in an anonymous Norse description. Apparently, it was not used extensively by the early colonies and it was not until 1782, when the first inspector of north Greenland came to the land, that coal was mined in such quantities that none had to be brought from Denmark. It has never been an important product of the country, although at times it has been used by ships within the region. Besides being exceedingly soft and friable, the seams are often situated high up along the steep cliffs, where mining operations are difficult.

DESCRIPTION OF THE COAL

The unmacerated lumps have been kept in the laboratory for about two years, where they have become thoroughly air-dried. Considerable cracking has occurred, which reveals the structure of the coal quite clearly. The different samples vary somewhat in hardness, but most of them, after drying, are quite friable, so that a lump of it may easily be crushed in the hand.

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[5] This and the two following paragraphs are summarized from Steenstrup, K. J. V., "Kulforende Dannelser i nord Grønland," Vedenskabelige Meddelelser fra Dansk naturhistorisch Forening i København, 25 (2–7). 1874.

The cracking which results from the drying of the lumps is usually irregular, like that of drying mud (Pl. I, Fig. 1). In some of the harder lumps there is a tendency toward a cubic cleavage such as develops in coals of higher grade (Pl. II, Fig. 1). However, this is not so common as the irregular splitting, and the specimens having a decided pitchy luster often show a crude conchoidal fracture (Pl. I, Fig. 2). Also there is a pronounced tendency for the material to split into plates parallel with the bedding planes (Pl. II, Fig. 2).

Some of the specimens show banding (Pl. III, Fig. 1), but in others the structure is quite homogeneous. In the former the layers can be identified as the "anthraxylon" and the "attritus" constituents, terms which have been coined to designate respectively the bright bands and the dull bands in American coals.[6]

The predominating color of the coal is black; only an occasional specimen shows any brown. One collection, which is highly calcareous and effervesces violently when treated with acid, has a grayish color. Occasional color displays characteristic of the so-called "peacock" coal can be observed on a few small bits.

In view of the black color and the irregular fracture shown by the coal under consideration, it seems that the term "subbituminous" is more appropriate than "lignite," which is the descriptive term generally applied to the soft coals from the west coast of Greenland. "Lignite" refers to the material which the Germans designate as *Braunkohle* ("brown coal"). This is a descriptive term based on its brown color, but the term has also been used for any coal which is below bituminous rank, but which is black and has an irregular fracture.[7] With respect to these characters much of the material at hand appears almost identical with a lump of subbituminous coal from the Philippines, which is figured by Campbell.[8] It is believed that this designation, and not "lignite," should be applied to the Greenland coal also.

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[6] Thiessen, R., and Francis, W., "Terminology in Coal Research," *U. S. Bur. Mines, Tech. Paper 446*. 1929.

[7] Campbell, M. R., "A Practical Classification for Low Grade Coals," *Econ. Geol.*, 3: 134–142. 1908.

THE PLANT REMAINS

The coal was macerated by soaking the lumps in dilute nitric acid. Some of it required about three months, but for other specimens more than a year was necessary. After the material had become soft it was treated with a dilute caustic solution until disintegration was complete. The plant fragments were then removed with fine forceps and mounted in glycerin jelly. This method, though slow, was not destructive to even the most delicate plant fragments.

A. Fragments of leaf tissue

Leaf fragments are the most common type of plant remains and were found in all the samples studied except a few which appear to consist entirely of carbonized wood or in which the coalification process had proceeded so far as to obliterate entirely all plant structures. It is probable that in the latter specimens decay was well advanced before coalification took place.

All the fragments were small, rarely being more than two millimeters in diameter. The preservation varies. Some of the more delicate ones show little or none of the original cell detail, but others are preserved with such perfection that they reveal structure as clearly as living material. The greater number of the well-preserved fragments are made up of cells with comparatively thick walls and suggestive of remains of leaves which were somewhat resistant to decay. Some of the more decayed ones were covered with hyphae, thus indicating that decay had gone on for some time before the material was buried to any great depth.

Considerable variety of vegetation is present. Most of the fragments resemble those of woody dicotyledons which grew in or near the original coal-forming swamp. Monocotyledons are indicated by epidermal fragments with cells arranged like those of the lily. Gymnosperms are indicated by fragments on which the stomata are arranged in parallel strips which are separated by spaces free from stomata (Pl. IV, Fig. 10). Besides these, there are numerous fragments with papillate guard cells, such as are observed in several genera of gymnosperms. Stomata very similar in structure and arrangement to those of *Sequoia sempervirens* were observed in one specimen.

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[8] *Ibid.*

Leaf remains of the lower forms of vegetation are not so abundant. In the material from Patoot, however, in the collections made at altitudes of 85 and 165 meters, the plant remains consist largely of light-colored fragments made up of rather rectangular cells, among which there are no stomata. A few remains of moss are recognized, but whether these very abundant fragments are remains of swamp-inhabiting mosses or other aquatic vegetation has not been ascertained. The only remains of moss definitely recognized are a few fragments of Sphagnum (Pl. IV, Fig. 9).

B. *Spores and pollen grains*

Objects distinguishable as pollen grains are rare in the Greenland coal. Spores, presumably pteridophytic, are more common and show considerable diversity of form. Material taken two miles inland from Skansen, at an altitude of 140 meters, contains several types. The largest are slightly in excess of one millimeter in diameter and are dark brown or black; the exine is deeply folded, so that the spore is covered with a network of irregular diaphanous appendages (Pl. III, Fig. 2). Since these spores are very opaque, it is difficult to identify the triradiate markings. On other smaller spores, which measure approximately 450 × 525 microns, the triradiate markings are visible if the spores are properly oriented. The appendages of these latter spores are slender flimsy structures, which are somewhat shorter, but otherwise resemble those of some species of the Paleozoic Lepidodendra. Both these types are possibly lycopodiaceous spores of some sort.

Figure 8, Plate IV, shows a spore more closely resembling that of a fern. The appendages consist merely of ridges of the exine, which are neither so deep nor so closely set as those described in the two specimens above. Its dimensions, 455 × 525 microns, are rather large for any common species of fern.

Other spores, suggestive of Isoetes, are of frequent occurrence (Pl. IV, Fig. 1). The triradiate markings are quite conspicuous and there appears to be a rim around the equatorial region. Reticulations are visible, but not conspicuous, and the entire spore is translucent.

In two specimens structures were observed which are suggestive of pollen grains rather than cryptogamic spores (Pl. IV, Fig. 3). This assumption is made solely on the basis of their shape and ornamentation. Cryptogamic spores, as a rule, are simpler.

C. Structures simulating bryophytic antheridia

Certain structures which are of uncertain identity, but which closely resemble the antheridia of the Bryophyta, are very common in certain of the collections (Pl. IV, Figs. 3–4). They are most abundant in the collections from the 140-meter level at Skansen, but they are occasionally encountered in material from other localities. When examined under the very low power of the microscope or with a hand lens, they appear as small amber-colored translucent objects, which were first thought to be seeds. A closer examination of these objects shows that they are hollow saclike structures with a wall consisting of a single layer of square or slightly rectangular cells. They are ovoid, pointed at both ends, and slightly broadest above the middle. At the apex there is a small pore which protrudes slightly and which is surrounded·by a definite circle of cells. The basal portion consists of cells which appear dark under the microscope, but its exact structure is not clear.

Figure 7, Plate IV, shows a similar object, which differs in details. It is shorter and relatively broader, the pore is flush with the surface, and attachment is by a slender basal stalk. The two types probably represent different species of closely related forms.

D. Remains of fungi

Although fungous mycelium is abundant, the reproductive structures were observed with certainty in only two specimens. Hyphal knots resembling perithecia of the Perisporiales occur sparingly. Septate mycelium is common and occurs on a variety of material. Some of the epidermal fragments, which appear to be badly decayed, are covered with mycelium to such an extent that the cellular structure of the host is obscured. Such fragments probably represent material which partially decayed previous to burial. Other specimens in which there is less decay and in which the hyphae can be observed protruding through the stomata suggest a parasitic relationship.

Another object encountered in the material from the 140-meter level at Skansen is a spherical object having a diameter of about 630 microns and densely covered with short hypha-like protuberances (Pl. IV, Fig. 6). These protuberances cover the object so densely that all structural features are obscured. Among the living fungi the gleba masses of certain of the Sphaerobolaceae germinate in a manner similar to this. All the spores of the mass put out germ tubes which soon cover the structure in a manner similar to that mentioned above.

Other objects always associated with fungous mycelium are numerous small spherical bodies about 70 microns in diameter. They are situated on and slightly sunken in the surface of leaf fragments. Superficially they resemble small fungous fruiting-bodies, but closer observation shows that they consist of dark granular material surrounded by a thin membrane. Of especial interest is one which can be observed in the process of fission (Pl. IV, Fig. 5). The new cell plate extends inward from each side for about one half of the radius of the cell. These objects are suggestive of algae of the Protococcus type.

EVIDENCE PERTAINING TO CLIMATE

Were we to know the Greenland flora in its entirety it is extremely improbable that the proportion of herbs to trees would be greater than is indicated by the previous studies of the leaf

PLATE I

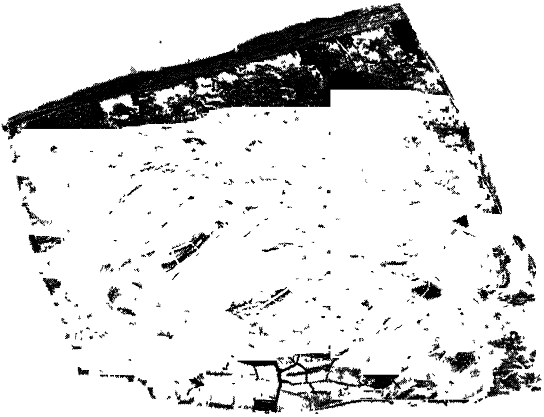


Fig. 1. Subbituminous coal showing pitchy luster and irregular fracture. From Atâ Delta, one mile southeast, at altitude of 250 meters. Slightly reduced

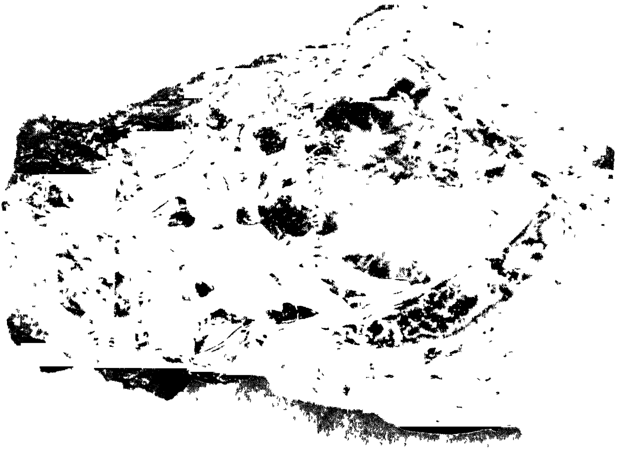


Fig. 2. Data as in Figure 1

PLATE II

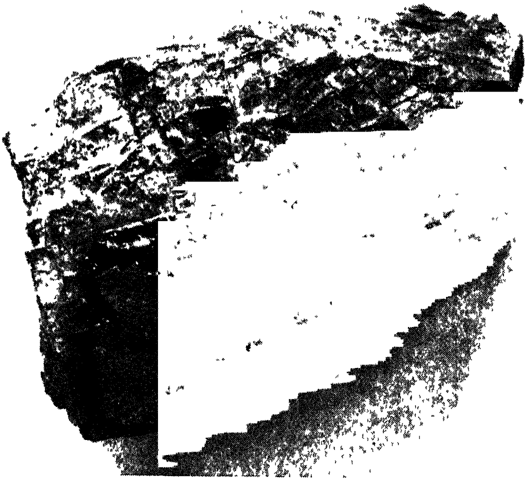


Fig. 1. Subbituminous coal showing tendency to cubic fracture, an approach to the bituminous condition. From Patoot, at altitude of 350 meters. Slightly enlarged

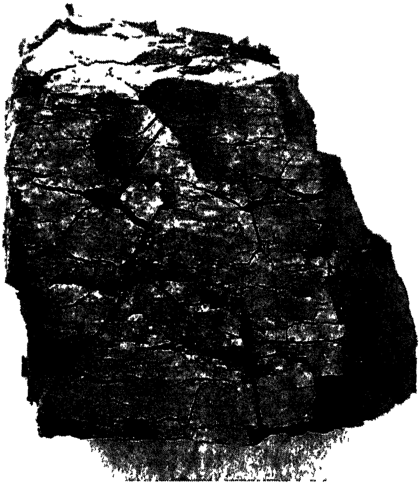


Fig. 2. Subbituminous coal showing tendency to check parallel to the bedding planes. From Amisut, at altitude of 6 meters. Slightly reduced

PLATE III

FIG. 1. Subbituminous coal showing banding. The narrow bands of anthraxylon alternate with the thicker attritus layers. From Amisut, at altitude of 1 meter. Enlarged about 2 times

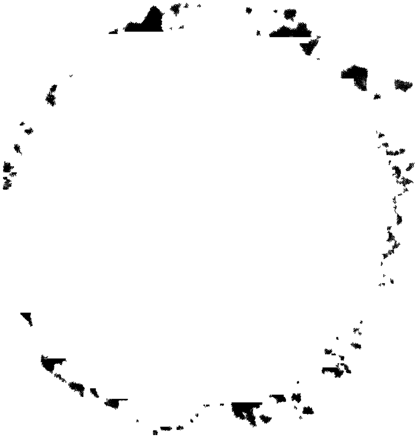


FIG. 2. Large spore showing appendages. From Skansen, two miles inland, at altitude of 140 meters. 1120 microns

EXPLANATION OF PLATE IV

FIG. 1. Spore showing triradiate markings. From Patoot, at altitude of 225 meters. 420 microns

FIG. 2. Antheridium of bryophyte (?). From Skansen, two miles inland, at altitude of 140 meters. 450 × 910 microns

FIG. 3. Pollen grain (?). From Skansen, two miles inland, at altitude of 140 meters. 525 × 540 microns

FIG. 4. Antheridium of bryophyte (?). From Skansen, two miles inland, at altitude of 140 meters. 455 × 805 microns

FIG. 5. Unicellular organism undergoing fission. From Amisut, at sea level. 70 × 90 microns

FIG. 6. Structure resembling germinating gleba of the Sphaerobolaceae. From Skansen, two miles inland, at altitude of 140 meters. 630 microns

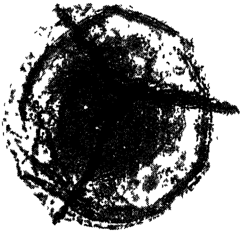
FIG. 7. Antheridium of bryophyte (?). From Skansen, one mile from coast, in bed of stream at altitude of 175 meters. 470 × 590 microns

FIG. 8. Spore, possibly fern. From Skansen, two miles inland, at altitude of 140 meters. 525 microns

FIG. 9. Fragment of Sphagnum leaf. From Skansen, two miles inland, at altitude of 140 meters. × 225

FIG. 10. Epidermal fragment, possibly from a conifer needle. From Skansen, two miles inland, at altitude of 140 meters. × 80

PLATE IV



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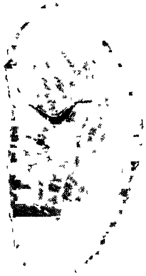

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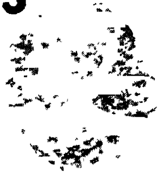

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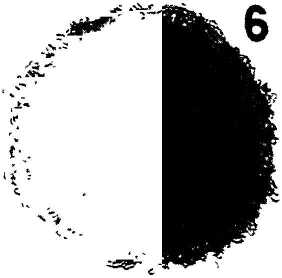

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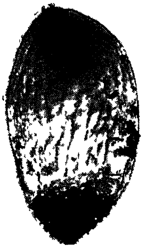

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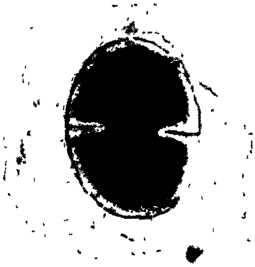

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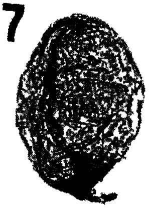

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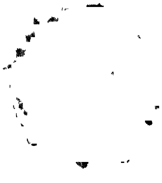

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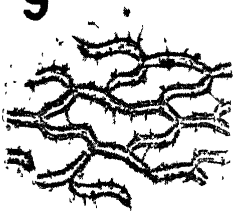

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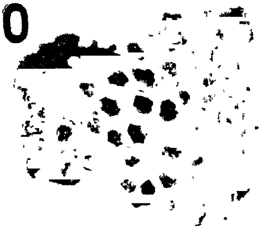

impressions. It is a recognized fact that the percentage of herbs and small shrubs in a flora becomes larger as the arctic region is approached, and it is possible that this has a direct bearing on the interpretation of climatic conditions in Greenland during Cretaceous and Tertiary times. Berry [9] has recently questioned the generally accepted idea that the late Mesozoic climate was tropical. He says that the flora thrived there under conditions much more northerly than has hitherto been assumed.

Because of the ability of plants to become adapted to different environmental conditions during the process of their evolution, it follows that a fossil form should not always be relied upon when one is attempting to determine the conditions under which it grew. A striking example of this is the genus Ginkgo, which, during Mesozoic times, was represented by several species and which had spread far beyond its present native limits. Since the fossil species of Ginkgo hardly indicate past climatic conditions over such a wide area which are similar to those of its native habitat in China, it follows that a fossil leaf from Greenland similar to a living leaf from Alabama is not by any means proof that the two leaves grew under similar climatic conditions. Also the sudden appearance of a world-wide angiosperm flora during Cretaceous times, which Darwin referred to as an "abominable mystery," shows that during this time angiosperm evolution was going on rapidly. With the sudden appearance of a multitude of new types came also adaptation to new conditions. It is just as possible that during upper Cretaceous times these plants were adapted to a cooler climate than they are at present, and that, were more of the herbaceous forms known, we would find in the upper Cretaceous of Greenland a considerable admixture of a more northern flora.

UNIVERSITY OF MICHIGAN

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[9] Berry, E. W., "The Past Climate of the North Polar Region," *Smithsonian Misc. Coll.*, 82 (6) : 29. 1930.

A THERMOPHILIC CALOTHRIX IN MICHIGAN *

LLOYD C. COCHRAN

THE appearance of a species of Calothrix, one of the blue-green algae, on the heating elements in constant-temperature water baths has given rise to the old question of thermal tolerance of algae and the source of such heat-tolerant forms.

In December of 1929 the writer observed a dense mat of algae growing on the surface of electric light bulbs which were used as heating elements in constant-temperature water baths. Examination of this growth revealed a Rivularia-like alga which was identified as *Calothrix thermalis* (Schwabe) Hansgirg. During February, 1930, the tanks were allowed to become completely dry, after which they were thoroughly cleaned and given three coats of heavy water-proof paint. The electric light bulbs were thoroughly cleaned with alkali cleaning powder and placed in a box, where they remained until January, 1931, when the tanks were again put into operation. Two weeks later the algae reappeared, growing vigorously on the surface of the light bulbs (Pl. V).

The species *C. thermalis* is extremely interesting in this habitat, since it has been reported by Tilden (1–2) from the hot water in the spillways of the geysers in Yellowstone Park. The operating temperature of the water bath of this experiment was 28° C., but that of the water in contact with the surface of the bulb must have been much higher. Since the most luxuriant growth of the alga occurred in contact with the surface of the bulb, it would seem that it should grow at higher temperatures.

A small flowing water bath was devised and heated with an electric hot-point heater so that the surface temperature could

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* The writer is indebted to Dr. E. A. Bessey for help and suggestions in the preparation of this paper.

be held at 40° C. and the bottom temperature at 30° C. Inoculations were made with scrapings from the original bulbs. After ten days algal growth could be seen in the bottom of the bath, but no growth was evident at the surface. After three weeks growth had progressed to the point of overflow at the top of the bath. Examination of the algal masses revealed the presence of several algae, some of which appeared to be growing even more luxuriantly than the Calothrix.

The temperature of the bath was again raised, so that the surface temperature was 50° C. and the temperature at the bottom was 40° C. The algae growing at the surface were entirely killed and no growth had occurred after ten days. After two weeks, however, growth reappeared at the point of overflow of the bath. Examination revealed several forms as shown in Plate VI. The Phormidia and Navicula seemed to be very heat-tolerant, since after three weeks they began to grow on the surface of the blade of the hot-point heater.

CONCLUSIONS

There are possibly a number of algae in Michigan, especially among the blue-green ones, which are growing at ordinary soil and water temperatures, but which may be heat-tolerant or even thermophilic in their temperature requirement. Owing to competition many of these forms may not be evident, but when competition is eliminated by high temperature, they may become suited to their environment and grow very luxuriantly.

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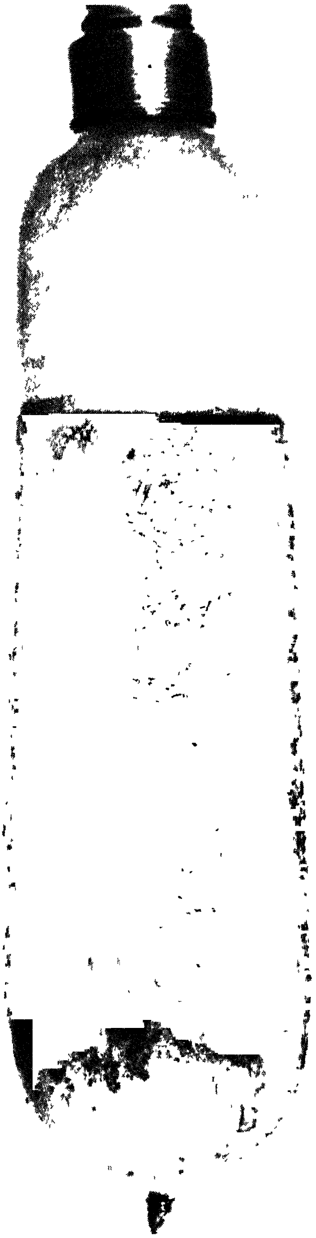
PLATE V



Electric-light bulb used as heating element in the constant-temperature tanks, showing the algal growth on the surface

EXPLANATION OF PLATE VI

Sketches of the forms found in the water bath at 50° C. (about × 450)

FIGS. 1–3. Stages in the development of *Calothrix thermalis* (Schwabe) Hansgirg

FIGS. 4–5. Two views of *Navicula sp.*

FIG. 6. *Spirulina sp.*

FIG. 7. *Chroococcus varius* A. Braun

FIG. 8. Green bacteria-like organisms

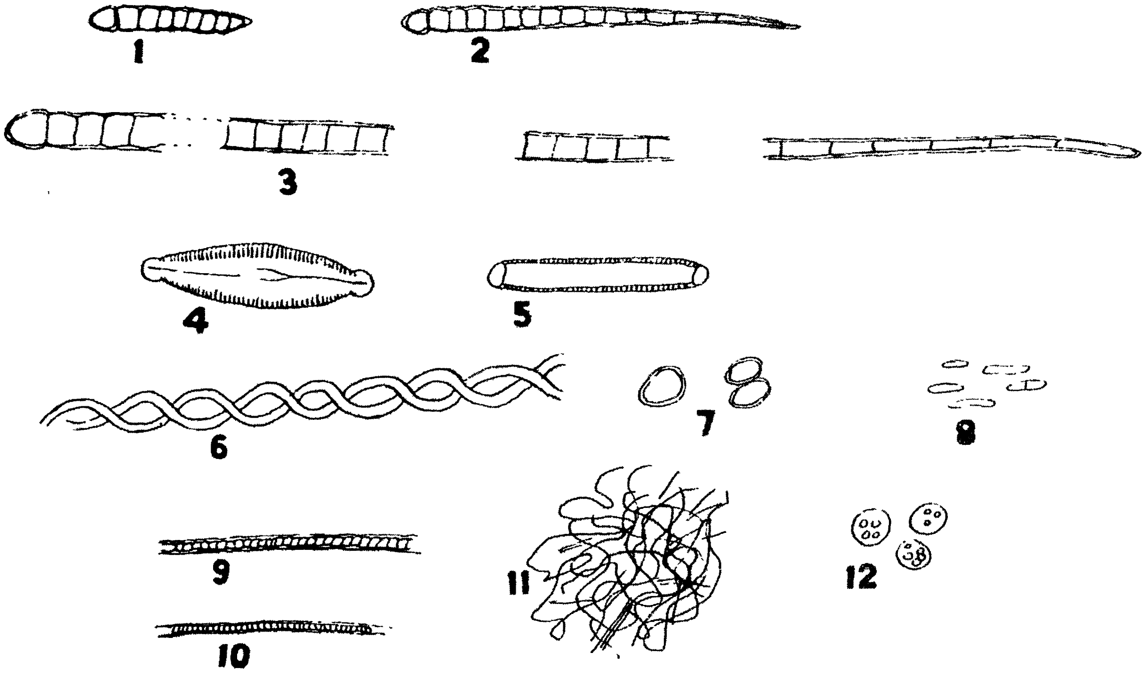
FIG. 9. *Phormidium tenue* (Meneghini) Gomont

FIG. 10. *Phormidium laminosum* (Agardh) Gomont

FIG. 11. Phormidium in mass, appearing reddish brown

FIG. 12. *Gloeocapsa aeruginosa* (Carmichael) Kützing

PLATE VI



PLANT VAGRANTS IN AMERICA

MELVIN R. GILMORE

EVER since the advent of Europeans in America the introduction of exotic species of plants has been occurring on this continent. Many have been brought in purposely and established with considerable care and expense by their human companions and friends. Others introduced themselves fortuitously, coming as furtive and undesired immigrants, stowaways; slipping aboard ship unnoticed on the other side, and slipping off again on this side, they established themselves as vagabonds and tramps in the new land before they were detected by their unwitting and unwilling hosts. Many of these species have been incorrigible weeds from the first, but some of the plants, cultivated as crops in Europe and brought here as such by the American colonists, escaped from cultivation and became weeds, and continuing so, have spread ever more widely over the continent of North America, and have become naturalized here, so that many persons unacquainted with their origin suppose they are native. A full account of all such escapes and naturalizations would make a large volume.

I shall here give an account of only a few of these globe-trotting species, in taxonomic order from lower to higher.

Among the grasses we find *Digitaria sanguinaris* (L.) Scop., commonly called crab grass, widely spread southward in North America.

Echinochloa crusgalli (L.) Beauv., barnyard grass, since its arrival has made itself quite at home in moist rich soil throughout most of the continent.

Setaria glauca (L.) Beauv. and *S. verticellata* (L.) Beauv., commonly called foxtail grass, have come from Europe and established themselves widely in cultivated and otherwise disturbed ground which is neglected.

Avena fatua L., wild oats, naturalized from Europe, is very common in the prairie provinces of Canada and in North Dakota, where it is mingled with grain crops and occurs in edges of fields and waste places.

Bromus secalinus L., cheat or chess, and a number of other species of Bromus abound in waste and neglected places.

Among the sedges introduced from Europe and now naturalized in extensive areas of North America we find *Carex leporina* L., *C. muricata* L., *C. arenaria* L., *C. caryophylla* Lat., *C. glauca* Scop. and *C. extensa* Good.

Of the Lily Family we find that *Asparagus officinalis* L., garden asparagus, introduced from Europe as a useful kitchen garden vegetable, has escaped from gardens and has become widely spread throughout the continent. Birds have been the disseminators of this plant. It readily and firmly establishes itself in new places of various conditions.

Of the Nettle Family we have *Cannabis sativa* L., hemp, which was introduced from Asia through Europe and is cultivated to a great extent in some parts of the continent for fiber. Birds have been the means of escape for hemp also, and it is widely distributed throughout the continent, maintaining itself as a weed.

Another member of this family, an undesirable immigrant which slipped in from Europe and has become naturalized over wide extent, is the great stinging nettle, *Urtica dioica* L.

We have a number of foreigners of the Buckwheat Family which have wandered far on this continent and have become firmly established. Among these are *Rumex obtusifolius* L., bitter dock, and *R. acetosella* L., sour dock or horse sorrel. All these have come to us from Europe and all are weeds, of which *R. acetosella* is especially pestiferous. Another member of this family, *Polygonum cuspidatum* Sieb. & Zucc., introduced from Japan, has become a nuisance in many places by taking complete possession of the terrain and growing so rapidly as to attain gigantic size in a short time. There is a part of the cemetery of the Chapel of Intercession on Broadway between 154th and 155th streets, New York City, which it is difficult to tend because of the rocky soil. Here this giant Polygonum has taken possession and defies dislodgment.

Several members of the Goosefoot Family have come to us from Europe uninvited and have established themselves here. Among them are *Chenopodium botrys* L., *C. bonus-henricus* L., and *C. album* L. The chenopodiums, especially *C. album* L., lamb's quarters, are good for pottage when cooked as "greens." They are related to our beets and spinach, both of which hold respectable places in our gardens.

From this family we have *Salsola kali* L. also, the so-called Russian thistle. This pestiferous plant came as a stowaway. On a farm near Scotland, Bonhomme County, South Dakota, in the spring of 1887 there was sown a field of flax. The seed was from Russia and was mixed with seeds of this weed which was to acquire the popular name "Russian thistle," because it is spiny and came from Russia, though it is not a thistle. From that place the plant has traveled and scattered its seeds in all directions. On maturing, the bushy top of the plant breaks loose at the surface of the ground and rolls away in the wind. It never stops tumbling so long as the wind blows and the way is open. In parts of the High Plains at certain seasons in windy weather tons of Russian thistles may be seen rolling over the country, bounding high in air and again tumbling on the ground, choking culverts and filling gullies. I have seen them caught in the telegraph wires of the Northern Pacific Railway in such quantities that they bulked like loads of hay suspended between the telegraph poles. Since its first establishment in South Dakota in 1887 this species of plant has spread over most of North America. Like any tramp, it has gone north as far as land is cultivated in northwestern Canada, and south into Mexico; it has gone east to the Atlantic and west to the Pacific. It thrives especially well in the arid and semiarid regions of the High Plains, the Great Plateau and the Desert.

Of the Pink Family we have several species of weeds which are all commonly called chickweed, comprising species of the genera Stellaria, Cerastium and Helosteum, and infesting fields, yards and roadsides.

The same family is represented by a number of pernicious weeds of the grain fields also: *Agrostemma githago* L., corn cockle, *Lychnis coronaria* (L.) Desr., mullein pink or campion, and several species of the genus Silene, commonly called catchfly or campion.

A coarse, bold, pushing member of this family which has widely established itself is *Saponaria officinalis* L., Bouncing Betty. In the eastern half of North America this plant is very common on margins of fields and along roadsides.

Of the Barberry Family one species has been introduced from Europe which has escaped and established itself over a quite varied and extensive range. This shrub, *Berberis vulgaris* L., common barberry, is the host of grain rust in one stage of its life cycle, and has caused great losses in grain crops and enormous expense and trouble in attempts to eradicate it from areas to which it has escaped.

The Mustard Family is one which not only has given us a large number of desirable immigrants as garden and field crops, but also contains several black sheep. Some of these are wholly undesirable vagabond plants and pernicious weeds. Perhaps the worst weed in this large plant family is *Thlaspi arvense* L., most commonly called penny cress, but in Manitoba, Saskatchewan and North Dakota called "Frenchman's weed" or "Frenchweed." It seems that the first appearance of this weed in the province of Manitoba was in a grain field on the farm of Mr. Violette, a French Canadian. From this fact Mr. Violette's French neighbors called it "l'herbe Violette," but his English-speaking neighbors simply called it "the Frenchman's weed" or "Frenchweed." L'herbe Violette is a curiously ironic name for this plant when it is considered that one of its most objectionable qualities is the characteristic odor emitted from its crushed seeds, an odor which is far removed from that of violets. For not only is this plant a troublesome weed in the growing season when it competes with crop plants, but the presence of its ripe seeds among the threshed wheat causes the loss of all the mill products contaminated with its potent garlicky odor. The grain fields of the prairie provinces of Canada have become badly infested with this weed, and it has crossed the national frontier into the states of North Dakota and Minnesota, and through them has traveled southward in grain transportation along the railways converging toward the great milling centers and depots of grain distribution.

Another member of the Crucifer Family is comparatively harmless, but almost ubiquitous. Probably most high school students have made acquaintance with this species very early in their botanical studies, even if they were never inclined to pursue the study of botany to any extent. The species to which I refer is *Capsella bursa-pastoris* (L.) Medic., shepherd's purse. This plant has been naturalized in America since very early colonial times. It was reported as present in New England early in the seventeenth century, so that it has almost as long a line of ancestors in America as have the members of the Society of Descendants of the Mayflower. From New England, where it arrived with the early colonists, it has migrated into the interior of North America wherever white people have settled, and now is common everywhere.

Sisymbrium altissimum L., tumbling mustard, is a rather recent immigrant of this family, but in the great grain-growing regions of the northern plains it has become extensively established. The strong winds and open country have been favorable to the dissemination of this plant, which breaks off when ripe and scatters its seeds as it rolls before the wind.

Radicula nasturtium-aquaticum (L.) Britton & Rendle, water cress, has become naturalized over a large part of North America.

Radicula armoracia (L.) Robinson, horseradish, was early introduced. It is exceedingly persistent where it has once become established, and clumps of it growing in fields often indicate the location of former kitchen gardens after all other remains of an abandoned habitation have disappeared. It has also escaped and established itself to some degree in moist places.

Very many of the members of that great family, the Leguminosae or Bean Family, have been introduced into North America from Europe, some as weeds and others as field crops. Some of those which were introduced as cultivated crops have escaped and naturalized themselves, taking the habit of weeds. On the other hand, *Melilotus alba* Desr., sweet clover, which first established itself as a despised weed, has in recent years enjoyed a sudden turn of fortune, and is now in high favor among farmers in wide areas of the continent. It is now sought and propagated as a desirable forage crop, and especially as a means of increasing or restoring fertility in soils lacking nitrates. It has been found also to have a very high value as a crop for bee forage. By the introduction of this plant as a field crop in North Dakota that state has come in a few years from a position of no importance in honey production to its present high place in that regard.

Melilotus became firmly established in Ohio between 1870 and 1880 through the activities of Mr. A. I. Root, the founder of the great apiary and apiary supply house at Medina. He learned of the value of this plant for honey production, and for this purpose he imported seed, which he would sow along the roadsides whenever he went driving about the country in his buggy.

The manner of introduction of this plant as a weed over a considerable area of northeastern Nebraska is very peculiar. In 1854 the Omaha nation by treaty with the United States surrendered title to all the lands of its national domain, retaining only a comparatively small area, thereafter to be known as the Omaha Reservation. The Omahas desired to have this reservation in the southeast corner of their former tribal domain, bordering on the Missouri and Platte rivers, and at the farthest possible distance from their deadly enemies, the Dakotas. It was in this location that they had their villages at the time of the cession. But the United States government desired them to remove their villages and accept for their reservation a tract in the northeast corner of their former tribal territory, in a location exposed to the forays of the Dakotas, who were also at that time hostile to the United States. Finally, the Omahas were coercively persuaded to accept the exposed location for their reservation, thus forming a buffer for the protection of the white settlers who came in and occupied the land formerly occupied by the villages and farms of the Omahas. The Omahas were promised full military protection against the danger from their enemies, but this promise was not fulfilled. Under this promise, but against their own judgment and desire, the tribe consented to move to the new location in the area now comprehended in Thurston County in the northeast part of Nebraska, along the Missouri River.

The Presbyterian Mission which served the tribe also moved to the new location and was assigned a tract of land upon which the mission buildings were erected. After a few years there appeared on the mission grounds a few plants of sweet clover, apparently from seed which had come among the effects of one of the new missionaries, and was thus unwittingly introduced from the East. As the plants grew and increased they were discovered and examined by the Omahas with interest. They found that this new plant yielded an odor resembling that of sweetgrass, which they held in such high esteem for use as incense and for perfume. The name of sweet grass in the Omaha language is *pezhe-zonsta;* therefore they named the new plant *pezhe-zonsta ega*^{n}, which means "resembling *pezhe-zonsta.*" When the people came to the mission they would pluck sprigs of sweet clover and carry them for the sake of their pleasing odor, and thus the seeds became scattered and produced plants along all the numerous wagon trails all over the Omaha Reservation. In this way sweet clover became abundant in that area as early as the second half of the nineteenth century.

The Umbelliferae, commonly called the Parsley Family or the Carrot Family, have furnished a number of desirable kitchen garden plants which were brought under cultivation from the wild state in Europe in prehistoric times. Members of this family, well esteemed and respectable in their cultivated form, are celery, caraway, dill, fennel, carrot and parsnip. Some or all of these have at times escaped from cultivation and become weeds. They have reverted to the wild forms which their ancestors had before they were domesticated in gardens many centuries or perhaps thousands of years ago. In reverting they become rude and rowdy and thrust themselves into many places where they are not wanted. They stand along the roadsides and fences mocking their well-bred, prosperous, cultivated relatives of the garden, and defying the gardener. One of the most abandoned and impudent of these escaped garden plants which have, as we say, "gone wild," is the wild carrot (*Daucus carota* L.). The wild carrot is very common along roadsides and in neglected fields in southern Michigan, Ohio, Ontario and New York. This plant is so different in appearance from the garden carrot that most persons never think of their being the same. But *D. carota,* when she breaks away from civilized, orderly, useful life in the garden, demands "freedom of self-expression" and insists upon "living her own life." Like some other creatures which demand the right to what they call "self-expression," Daucus seems bent upon expressing her worst instead of her best, and, like these others, in living her own life she leads an existence neither glorious nor useful, and quite intolerant toward all others.

Because of the lacy umbel of white flowers which the wild carrot wears it is popularly called "Queen Anne's lace." Although simply the garden carrot escaped from cultivation, it is one of the very worst weeds. It was introduced from Europe, but is now widely disseminated on this continent and is rapidly spreading in old pastures and along roadsides.

Several members of the Mint Family have been introduced from Europe. One of the most common of these is *Nepeta cataria* L., catnip or catmint. It is a plant in much esteem among the common folk remedies of Europe, especially for ailments of children. When the early colonists migrated to America they brought catnip with them to plant near their dwellings in the New World. As white settlements pushed farther into the interior they carried catnip along. From these plantings the species escaped and has become extensively dispersed.

A curious thing about this plant is the great lure which it has for cats. If a cat has not had access to catnip for a long time a sprig will throw it into raptures of delight. It will hold the sprig in its paws and rub and smell it and roll over and play with it, paying no attention to anything else for the time being. What is still stranger, this species of plant, coming originally from Asia, not only has this strong lure for the domestic cat, which also came from Asia through Europe to America, but holds an equally strong lure for all the native American species of the feline family. Since this fact has been discovered professional trappers use catnip as a lure for their traps to catch any species of American wildcat. It would seem as if in the long geologic past the common ancestor of all the cat family had formed a great liking for this species of plant, from a common center of origin. Apparently, the remote ancestors of all our wildcats, lynxes, mountain lions and others, migrating into North America, had carried in their constitutions the appetite for catnip. But the plant did not find its way here till ages later from the other direction through Europe, from which it was brought in the seventeenth century by the English colonists. Was the appetite for catnip carried dormant through countless generations of the ancestors of American wildcats and mountain lions and then at last wakened by the scent of the plant when they were brought together again?

Another member of the Mint Family introduced from Europe and now widely naturalized in North America is *Prunella vulgaris* L., commonly called self-heal or heal-all. It was considered a valuable remedy among the herbals in European folk remedies. It may, therefore, have been introduced purposely by the colonists, or its seeds may have dropped casually from dry sheaves of the herb brought out for remedial use. It adapts itself to various situations and conditions and is now common all over the country.

The Potato Family (Solanaceae) has furnished a large number of useful species for cultivation, both from those species native in the Eastern Hemisphere and from those in the Western. A number of species of this family which have never been cultivated have economic uses. A weed, *Solanum dulcamara* L., from Europe has become naturalized and is now very common throughout eastern North America in various situations.

Of the Figwort Family one species introduced from Europe has naturalized itself and become a common weed in all eastern North America from the Atlantic to the Missouri River, and that is *Verbascum thapsus* L., commonly called mullein. Cutler's

"An Account of Some of the Vegetable Productions naturally growing in this part of America botanically arranged" (1785) mentions it as being common in New England in his time.

Another species of this family, *Linaria vulgaris* Hill., a European wanderer in America, now has an extended range. This plant is commonly called butter-and-eggs. A fact which seems to me peculiar in connection with the distribution of this plant is that I have always found it about the sites of old military posts, even if nowhere else in any observed region. In such situations I have seen it in many places in Nebraska where old military posts have once stood, and all the way thence northward through South Dakota and North Dakota to old Fort Pembina near the Canadian border.

Of the Plantain Family *Plantago major* L., an early comer from England, is mentioned by John Josselyn in his "New England Rarities Discovered" (1672) as being common at the time of his writing. At that time the Indians had given it a name meaning "Englishman's foot," because, they said, it soon became established wherever Englishmen set foot. Since then it has spread all over North America.

In northeastern North America from New England to Michigan one member of the Teasel Family, the common wild teasel, *Dipsacus sylvestris* Huds., originally from eastern Europe, has become prevalent along roadsides and in neglected fields. The cultivated teasel, *D. fullonum,* has been imported for drapers' use. It seems to be a form of *D. sylvestris,* the latter being simply *D. fullonum* reverted to the original wild form.

The largest family of phaenogamous plants is the Composite Family. This includes a number of species cultivated as garden esculents, such as artichokes, endive, escarole, chicory, lettuce, sunflowers and "Jerusalem artichokes," which are not artichokes and did not come from Jerusalem. Chicory is cultivated as a green salad vegetable and also for its bitter roots, which are dried, roasted and ground for use as a substitute for or an adulterant of coffee. It was introduced from Europe into America in cultivation. It has escaped here, and now its blue flowers are to be seen along the roadsides in many places.

The common oxeye daisy (*Chrysanthemum leucanthemum* L.), an early introduction from Europe, has established itself firmly in many old pastures. Another of this family which came early with the colonists, being mentioned by Josselyn as common when he wrote in the seventeenth century, is the dandelion (*Taraxacum officinale* Weber.), which has made itself almost ubiquitous.

Common tansy (*Tanacetum vulgare* L.), which was introduced by the early colonists, has been carried throughout the continent by settlers. Clumps of it appear in many places as relics of old gardens.

Several European species of Artemisia have been introduced into North America at different times and in various places by early colonists and later settlers from a number of countries of Europe. Josselyn (1672) mentions the presence of wormwood in New England in his time, and it is listed by Cutler and also by Gerard. *Artemisia absinthium* L. is naturalized in many places along the northern border of the United States, where it escaped and established itself during the time of French occupation. This plant is found in places of old French settlement throughout the Great Lakes region, and I came upon clumps of it growing in the woods along the Pembina River in North Dakota, not far from the confluence of that river with the Red River of the North, where the species has persisted since the French fur traders had their establishment there.

Artemisia absinthium has become naturalized within the last thirty years in many places over a wide area of central South Dakota, and also in west-central North Dakota, where it has escaped from the garden plantings made by the Germans from Russia who have settled in these regions in large numbers and have brought with them the habits and ways of living which they had in Russia. Now in central South Dakota and North Dakota there are areas in which *A. absinthium* has become the dominant species of vegetation for long stretches along the roadsides and over a great extent of pastures and old fields.

Arctium lappa L., the common burdock, introduced from Europe, is widely naturalized in North America. During the times of migrating and freighting across the continent by oxteam this plant became established along all the military roads, the Mormon Trail, the Oregon Trail, and other transcontinental trails from the Missouri River westward.

Cirsium arvense (L.) Scop., which is called Canada thistle in the United States, because it invaded our country from Canada, came into North America from Europe and has spread southward in the United States at least as far as Nebraska.

Tragopogon porrifolius L., commonly called salsify, has escaped from gardens and become established as a weed, and its purple flowers are a feature of the vegetation of roadsides and old fields over a large part of the continent.

Tragopogon pratense L., goat's beard, has also become naturalized widely over North America, from the Atlantic seaboard westward, but especially in the plains, where it has become very abundant even in the undisturbed native turf. Its pale yellow flowers and later globes of white plumose pappus have become a feature of the late summer landscape of the High Plains, where prevailing strong winds favor its dissemination.

The perennial sow thistle (*Sonchus arvensis* L.) from Europe has become naturalized in the grain-growing prairie provinces of western Canada and has made great devastation in the fields of Manitoba and Saskatchewan. From Manitoba it has invaded North Dakota along the branch lines of the Great Northern Railway and has traveled along that route by means of grain cars to the headquarters at Saint Paul, Minnesota. This forms a new distributing point to all places where these cars may later travel along the Great Northern and connected lines of railway. About 1910 the sow thistle was beginning to invade North Dakota on its northern border. By 1916 it was common as far as Grand Forks, and was appearing occasionally still farther toward the south in North Dakota and Minnesota. Then the Great Northern and the Burlington railways were merged and operated as one system. Thus this weed had a great new area opened to it for its travels. By 1918 it appeared along the Burlington lines as far south as Lincoln, Nebraska. In such manner modern systems of transportation facilitate the rapid increase in the extent of weed invasion.

Prickly wild lettuce (*Lactuca scariola* L.), introduced from Europe, has become naturalized over a wide extent on this continent.

Orange hawkweed or devil's paintbrush (*Hieraceum aurantiacum* L.), from Europe, has become naturalized and is a pernicious and persistent weed in pastures and old fields in the eastern states.

I have not attempted to give an exhaustive list of the flowering plants which have invaded this continent from Europe and have become naturalized here; such a list would be too long for our present purpose. I have given only some of those which are in some way more notable or troublesome or more interesting than others.

The migration of plants has not all been from Europe to America. Many American species have gone to Europe, some by invitation and some without, and have become permanent elements in the plant population there. One of our native American plants which has been received in some countries of Europe with very great favor is the sunflower (*Helianthus annuus* L.), cultivated for its seeds as a food crop. This plant is indigenous to the plains of North America. In remote prehistoric times the Indians of the Southwest discovered the food value of its seeds, and they brought it into domestication and by cultivation and selection improved it to its present size and quality. Its cultivation was carried eastward from tribe to tribe to the Atlantic seaboard. From there it was introduced into Europe in colonial times. The use of sunflower seeds did not attain popularity among the colonists, nor among the people of western European countries. But its reception in eastern Europe was very different, especially in Russia, where it became exceedingly popular. The sunflower was unknown anywhere in Europe before the discovery of America. The so-called "Russian sunflower" that is cultivated in gardens in this country is not Russian, but an American sunflower which has been abroad and has come back home again.

The effects of and reasons for selective popularity of a plant among the people of one country, and indifference or dislike toward it by the people of another country, are interesting and curious. The Indians prized the seeds of the sunflower for their high food value, and for that reason they brought the plant into cultivation. And it was its value as a source of fat in the dietary which made the sunflower so popular in Russia when it was introduced there. But why should its value have been recognized and gained such glad acceptance in Russia, when it was treated with indifference by people of other countries? The reason is most interesting. The Holy Orthodox Russian Church was very rigid in its restrictions in regard to certain articles of food forbidden during the forty days of Lent and the forty days preceding Christmas. The Church required the faithful to abstain not only from eating meat during these periods, but also from dairy products, milk, cream, butter and cheese. When the sunflower seed was introduced into Russia and the people became acquainted with its properties they hailed this acquisition with great joy, for here was a good fat aliment which supplied all that their appetite demanded, and yet there was no interdiction of the Church against its use during periods of fasting. Because it was something which had not been known to the church fathers when the fasting regulations were formulated, therefore the people felt no compunction about indulging in this rich, fat food to their full satisfaction. Thus sunflowers gained the great popularity which they enjoy in Russia, and every family which has a garden raises some sunflowers as a staple crop. From these circumstances it has resulted that sunflowers have escaped from cultivation in that country and have reverted to the wild form in waste places all over the Russian steppes. So I was informed by Dr. Charles Edwin Bessey, who had made the observation during his visit to that country. Dr. Ernst A. Bessey, who spent some years in botanical exploration in Russia, also told me that the sunflower, escaped there from cultivation, has made itself quite at home and is perfectly naturalized. He likewise informed me of the remarkable fact that all these naturalized and reverted sunflowers in waste places and neglected fields of Russia have only yellow florets in the discs, but never reddish purple, as many of the wild *Helianthus annuus* have on our western plains. This would indicate that all the cultivated sunflowers of Russia, the genealogical stock from which are descended all the escaped and reverted sunflowers of that country, had only yellow florets and not purple.

In this discussion I have indicated some of the alluring paths of exploration into the interrelations of plants and men. Such are some of the fascinating surprises and charmingly unexpected issues which meet the ethnobotanical adventurer. Here we have found a long and intricate path revealing the ultimate vital connections, in spite of great remoteness in time and immense geographic distance, between the prehistoric agriculturists of the Western Hemisphere and the thinkers and teachers of a religious cult which arose in one of the little countries at the eastern end of the Mediterranean Sea, an unimportant little country which was subject to the Roman empire, but from which came a spiritual power that has made itself felt in all parts of the world. We see one of the disciplinary regulations of a branch of that cult exercising an influence upon the acceptance, by millions of people of different race and of entirely different culture pattern and thousands of miles away, of one of the products of that remote, prehistoric agriculture of the New World.

University of Michigan

PLATE VIII

A typical diploid eggplant from the same culture as that in which the triploid plant occurred

PLATE VII

Triploid eggplant, in the field

A POLYPLOID EGGPLANT, *SOLANUM MELONGENA* L.*

EDAVALETH K. JANAKI-AMMAL

IN THE summer of 1929 a number of unfruitful plants were observed in a large culture of F_2 plants of a cross between a dark purple and an "ivory"-fruited variety of *Solanum melongena* grown at the Botanical Gardens of the University of Michigan. The plants were prominent in the field because of their unusually large leaves, stout stems and more erect habit of growth. They were taken into the greenhouse in the fall, but died before any cytological work was done on them.

In the summer of 1930 a single plant (Pl. VII) that showed the type of vegetative growth described above appeared in a culture of 100 F_1 plants of a cross between a dark purple and a green-fruited eggplant. Cytological examination of this plant showed 36 chromosomes in the cells of the root tip. The somatic number in the eggplant is normally 24, and this number was observed by the writer in the root tips of the two parent plants and in their normal hybrids. The single abnormal plant is, therefore, a triploid.

The normal F_1 plants (Pl. VIII) were intermediate in regard to the development of authocyanin in the stems and leaves. The fruit, which was borne abundantly, was a medium purple on green. The triploid plant had dark green leaves and stem, like those of the male parent. A single small fruit produced in the field by open pollination showed faint streaks of purple on green. The hybrid nature of the triploid plant is, therefore, unquestionable. Genetical and cytological studies of this plant are being made.

UNIVERSITY OF MICHIGAN

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* Papers from the Department of Botany, University of Michigan, No. 356.

CHROMOSOME CONFIGURATIONS DURING THE HETEROTYPIC PROPHASE AND METAPHASE IN CERTAIN OENOTHERAE AND THEIR GENETIC SIGNIFICANCE *

CHANDRAKANT G. KULKARNI

OENOTHERA FRANCISCANA RACE D

INTRODUCTION

OF ALL the wild species of Oenothera that have been brought under cultivation *Oenothera franciscana* Bartlett (1914) is one of the most interesting because it is one of the few that are apparently homozygous. The chromosomes of *franciscana* are characteristically paired at diakinesis and metaphase of the heterotypic division (Kulkarni, 1929*b*). Its pollen is almost perfect, and the seed fertility is very high. This species has, however, given some variants in its progeny from self-pollinated seed in the cultures of both Professor Davis and myself. Only one of these has been cytologically examined so far, and that is the haploid "pointed tips."

The cytology and the genetics of this haploid have already been published (Davis and Kulkarni, 1930). It was pointed out that, when a haploid is self-pollinated, it gives rise to plants the majority of which resemble diploid *franciscana*, although a small number of plants morphologically distinct from the latter appear.[1] The synthetic *franciscana* thus obtained resembles *Oe. franciscana* Bartlett very closely in all its morphological characters. The leaves, bud cones, sepal tips, hypanthium, the shape

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* Papers from the Department of Botany of the University of Michigan, No. 354.

[1] Four such types have been observed, but since their cytology has not been worked out it cannot be definitely stated at present whether these are due to gene mutations or mutations produced by irregular distribution of chromosomes.

and the size of the flowers and capsules, the growth habit and the time of flowering of this plant are similar to those of *Oe. franciscana* Bartlett. In only one respect, so far as I am aware, is this plant different from the latter: it is not quite so vigorous. In this paper *Oe. franciscana* Bartlett will be designated *franciscana* B and the synthetic *franciscana* obtained from the self-pollinated seed of the haploid "pointed tips," *franciscana* D, so that the two strains may be easily referred to without any confusion in future genetical and cytological work.

The pollen of *franciscana* D, like that of *franciscana* B, is almost wholly good. The seed fertility is also as high as that of *franciscana* B (90–92 per cent).

MATERIAL AND METHODS

The cytological material for this study came from three plants, 52–1, 52–12 and 52–43, progeny of the haploid 1–118 from *franciscana* B. Three fixations were made from each plant, nine in all. The methods of collecting, fixing, dehydrating, clearing, embedding, cutting and staining were the same as those used in former investigations (Kulkarni, 1929*a* and 1929*c*). Again, as in the past, one of Allen's modifications of Bouin's solution, strong Flemming and Zenker's solution, was found to be excellent for diakinesis and later stages.

Pollen counts were made at intervals from buds selected at random from the plants from which fixations were secured. The results of these counts showed that the average of good pollen is 90 per cent.

DESCRIPTION OF THE CHROMOSOMES

In the early stages of diakinesis seven pairs of chromosomes are distinctly visible (Fig. 1). They are rather long and irregular in outline. A little later the bivalent chromosomes condense rapidly and in the final stages of diakinesis seven pairs of chromosomes are clearly seen (Figs. 2–3). A thorough study was made of 374 cells that showed this stage. Only the nuclei that showed four or more pairs of chromosomes were recorded. In 50 nuclei all seven pairs of chromosomes were present; 96 had six pairs;

150, five pairs; the remaining 78, only four pairs. In no case did I observe the closed chain of four chromosomes found in some strains of *franciscana* B.

The nuclear membrane very soon disappears and a multipolar spindle is formed from the delicate fibrils which have previously appeared in the cytoplasm. The seven pairs of chromosomes, which are perfectly ring-shaped and much more condensed by this time, are seen in the equatorial region (Fig. 4).

The multipolar spindle becomes bipolar and the chromosome pairs soon become arranged in a definite plate. During the heterotypic metaphase the spindle fibers attach themselves to the mid-region of the U- and V-shaped chromosomes (Fig. 5). Soon after, the chromosome pairs are pulled apart; seven chromosomes normally reach each pole (Fig. 6).

After the chromosomes reach the pole they become arranged in a small star-shaped cluster, with one chromosome in the center and six at the periphery.

Some time later the chromosomes split lengthwise, but the split is not conspicuous at this stage. Presently a nuclear membrane appears around each set of daughter nuclei. The nuclei are rather small at this stage, but enlarge rapidly by the increase in the cytoplasmic volume. While these events are happening, the lengthwise split in the chromosomes becomes distinctly visible. The two components of the split chromosomes are rather straight at first, but very soon their arms bend slightly and they appear like irregular X's. The chromosomes, which are rather closely aggregated at first, later take on a distinctly peripheral position (Fig. 8).

Non-disjunction occurs during the heterotypic anaphase in the nuclei of some sporocytes. This results in eight chromosomes going to one pole and six to the other (Fig. 7). A careful survey of 500 nuclei at this stage was made with a view of getting some information on the percentage of cells in which non-disjunction takes place. Thirty-six nuclei showed eight chromosomes in one cell and six in the other, which is an irregularity of 7.2 per cent. The remaining nuclei were perfectly normal, seven chromosomes being observed in each.

The X-shaped split chromosomes start condensing and nucleoli begin to appear in conjunction with the chromosomes or, rarely, with the chromatic threads spun by them. The condensation of the chromosomes proceeds still further and they become quite compact and finally appear as short rods (Fig. 9). Presently the nuclear membrane disappears. The spindle for the homeotypic division is formed from the fibrillae that develop in the cytoplasm. These enter the nuclear cavity with the dissolution of the nuclear membrane (Fig. 10). The processes involved in the formation of the spindle resemble those of the heterotypic division.

During the prophases there are frequently seen multipolar spindles (Fig. 10) which soon become bipolar (Fig. 11). The seven split chromosomes come to the equatorial plate in the usual manner. The fibers attach themselves to the perfectly paired daughter chromosomes and these are then pulled apart and pass to the poles, seven chromosomes in each set (Fig. 12). The homeotypic mitosis is regular except where there has been an irregularity in the preceding heterotypic division, in which case eight and six chromosomes may be distributed instead of the normal seven.

DISCUSSION

Cleland (1922) has described the chromosome configuration at meiosis in *franciscana* race B. He found in late prophase a closed chain of four chromosomes and five ring-shaped pairs of chromosomes. In other material this species has likewise shown a closed chain of four in early prophase stages, but this chain invariably breaks into two pairs at diakinesis (Kulkarni, 1929*b*). *Franciscana* B presents, therefore, two kinds of plants, one having a chain of four chromosomes and the other having no chain at all, but seven uniform ring-shaped pairs of chromosomes. Although both types of plants are morphologically alike, still they present slightly different chromosome configurations, as discussed above. In breeding work this fact is quite significant because the genetical results are likely to differ in the case of the two plants under discussion. It is known that the strain of *fran-*

ciscana B which shows a chain of four chromosomes produces two types of gametes (Emerson, 1931).

In *Oe. franciscana* race D all chromosomes pair perfectly at diakinesis, as expected, because there are two chromosomes of each kind present. Hence, normally, this plant should produce only one type of gamete. Crosses have been made to ascertain the gametic constitution, but since these studies are not yet complete they will not be discussed here. It can be stated, however, that such a plant holds a great interest in Oenothera genetics because there is no heterogametism to complicate the study of its progeny. The other decided advantage is that both the pollen and seed fertility of this plant are very high.

In *franciscana* race B non-disjunction sometimes occurs during the heterotypic anaphase that results in the abnormal distribution of the chromosomes, eight chromosomes going to one pole and six to the other. The pollen grains with eight chromosomes may possibly function and give rise to plants having fifteen chromosomes. Such individuals will belong in all likelihood to the set of seven or more possible non-disjunctional types. In addition to these non-disjunctional types, one triploid (or possibly two) and a tetraploid are what may be logically expected (Kulkarni, 1929*b*) to appear sooner or later in every species of Oenothera.

As already shown in this paper, there are also some irregularities in the distribution of chromosomes at the heterotypic anaphase in the sporocytes of *Oe. franciscana* race D. These produce abnormal gametes, which, when united with the normal gametes, give rise to forms that are morphologically distinct from the parent. As in *franciscana* B, triploids also are possible in *franciscana* D. Plants resembling triploids and other non-disjunctional types have been observed in my cultures of *franciscana* D, but since their cytology has not yet been worked out it is impossible to state their exact nature.

It is worth noting here that *Oe. franciscana* race D is also capable of giving haploids in its progeny from self-pollinated seed. Culture 52, grown in 1929, had 400 plants, of which one was a haploid; and culture 68, of 1930, consisted of 500 plants, one of them a haploid. The ratio of *franciscana* B to haploid is about 1000 : 1 (Davis and Kulkarni, 1930); that of *franciscana* D to haploid is about 500 : 1. These two haploids from *franciscana* D have in all likelihood arisen through the parthenogenetic development of the egg, and they give additional strength to the view that this is the manner of origin of haploids in flowering plants.

Haploids have been obtained in Datura by the application of the pollen of *D. ferox* to the stigma of *D. Stramonium* (Belling and Blakeslee, 1923, 1927). They have likewise been obtained in the F_1 cross of *Nicotiana tabacum* × *N. sylvestris* (Clausen and Mann, 1924). Again, Gaines and Aase (1926) have obtained a haploid in attempts to pollinate a hybrid of Triticum from Aegilops. Hollinghead (1928) reports two haploids of *Crepis capillaris* from the F_1 of the cross *C. capillaris* × *C. tectorum*.

In order to ascertain whether haploids can originate in this manner in Oenothera, a cross was made involving *Oe. franciscana* race D as the pistillate parent and *Oenothera argillicola* Mackenzie as the staminate parent. Five hundred seeds of this cross were planted and 450 seedlings were obtained. Of these seedlings, 448 had the distal ends of their cotyledons distinctly yellow; the other two were entirely green. The rosettes were set in the field in early May. Most of the rosettes were yellow except the two that were green. Gradually the rosettes started to die in the field; at the beginning of June all the rosettes died except the two mentioned above and these turned out to be haploids.

In conclusion, I desire to emphasize the genetical importance of this plant with its high pollen and seed fertility, seven pairs of homologous chromosomes, and no heterogametism to complicate the study of its progeny. Such a plant should make ideal material for inheritance studies, provided no lethal factors appear to complicate the situation. The inheritance studies with this plant and its like should throw light on some of the much-discussed problems in Oenothera genetics.

OENOTHERA ARGILLICOLA

Oe. argillicola Mackenzie (1904) is a very beautiful primrose with large flowers about 7–8.5 cm. in diameter. The style is very long, so that the stigma protrudes from the bud before it opens. The calyx is glabrous. The capsules are rather broad and woody at the base and are inserted perpendicularly to the axis of the spike. They are strongly arcuate and narrowed to a very slender apex. It is a small compact plant, with exceedingly narrow leaves, dark foliage and purple stems.

Plants were grown from the seeds collected by Professor H. H. Bartlett at White Sulphur Springs, Virginia. Four generations (2000 plants in all) have been grown and so far this species has not given any variant from the type. The four plants from which the cytological material was collected came from a line self-pollinated for four generations.

At the final diakinesis stages seven uniform ring-shaped pairs of chromosomes are observed (Fig. 13). These are brought to the equatorial plate (Fig. 14) and are distributed to the two poles in a very regular manner, seven reaching each pole.

Although this species has all the favorable characteristics, high pollen and seed fertility (92 per cent), pairing chromosomes and many contrasting characters with respect to other species, still it is practically worthless for inheritance studies, since it has consistently given in some crosses plants that do not live to maturity, but die in seedling stage. This species has one important use, however, in that its pollen has been successfully used on the stigmas of certain other species of Oenothera for the artificial production of haploids, as discussed elsewhere in this paper.

OENOTHERA NUMISMATICA

Oenothera numismatica Bartlett (1914, 1915) is morphologically similar in many respects to *Oenothera pratincola.* This species has been carried on in a selfed line for fifteen generations and has bred remarkably true to type. In this respect it differs from *Oe. pratincola,* which in every generation gives various types of mutations from self-pollinated seed. A cytological study of the chromosome behavior in the sporocytes of *Oe. pratincola* was presented in an earlier paper (Kulkarni, 1929*a*) and, as will be shown presently, the chromosome configurations in diakinesis and metaphase in *Oe. numismatica* resemble those of *pratincola* in very many respects. Three plants were examined cytologically.

The sporocytes of *Oe. numismatica* show a closed chain of fourteen chromosomes attached end to end (Fig. 15) at the final prophase stages. The arrangement of the chromosomes at this stage in this plant resembles that in *Oe. pratincola.* At the heterotypic metaphase the chain of fourteen chromosomes (Fig. 16) is brought to the equatorial plate, where the spindle fibers attach themselves to the chromosomes in such a way that the alternate chromosomes pass to the opposite poles. Irregularities in this method of separation of the chromosomes at the heterotypic anaphase in this species are very rare. This behavior is quite in contrast with that of *Oe. pratincola,* which shows an irregularity of 30.1 per cent.

Oe. numismatica, when crossed with some other species, gives twin hybrids, thus showing that two types of gametes are produced. The chromosome configuration described above explains this genetical behavior.

OENOTHERA NUMISMATICA MUT. ROBUSTA

Oenothera numismatica mut. *robusta* arose in the progeny of the cross mut. *recidiva* × *Oe. numismatica* in the garden of Professor Bartlett and Dr. Blanchard (Blanchard, 1926; Kulkarni, 1929*c*). This plant is thick in all of its parts and rather cylindrical. It is taller than *Oe. numismatica.* The side branches are few and erect. The buds are very thick. The pubescence of the buds resembles that of *Oe. numismatica* and the flowers are as large as those of the latter. Fifty per cent of the pollen is shriveled. This mutation has bred true from self-pollinated seed for six generations. Three plants were examined cytologically.

The pollen mother cells of all the three plants examined showed a closed chain of fourteen chromosomes attached end to end and one free chromosome (Fig. 17) at the final stages of the heterotypic prophase. During the heterotypic metaphase (Fig. 18) in the majority of the pollen mother cells the adjacent chromosomes in the chain become attached to fibers passing to the opposite poles and the zigzag arrangement is observed. The free chromosome goes to one or the other pole, depending upon the attachment of the fibers. As a result, eight chromosomes always pass to one pole and seven to the other.

With the type of chromosome configuration described above, two types of gametes are produced, one with eight chromosomes and the other with seven. Since this mutation breeds true from self-pollinated seed, it appears that the eggs with eight chromosomes and the sperms with seven chromosomes function and give rise to zygotes which produce fifteen-chromosomed plants. The other types of gametes, sperms with eight chromosomes, and eggs with seven chromosomes, are abortive and do not functon. This is proved by the fact that when the pollen of this mutation is used to pollinate the parent species it gives nothing but *typica* plants.

OENOTHERA REYNOLDSII

Oenothera Reynoldsii Bartlett (1914, 1915), like *Oe. pratincola,* has given rise to some very interesting mutations. Chief among these are muts. *bilonga, rigida, dentifera, semialta* and *debilis.* Three plants of *Oe. Reynoldsii,* two plants of mut. *bilonga,* and two plants of mut. *rigida* were cytologically examined.

Oe. Reynoldsii shows a closed chain of fourteen chromosomes (Fig. 15) at the final stages of the heterotypic prophase. During the heterotypic metaphase (Fig. 16) adjacent chromosomes pass to the opposite poles, so that a regular zigzag arrangement of the chromosomes is distinctly observed in the majority of the pollen mother cells.

It is known that this species produces two types of gametes. The chromosome configurations described above explain the genetical behavior.

OENOTHERA REYNOLDSII MUT. BILONGA

In *Oe. Reynoldsii* mut. *bilonga* (La Rue and Bartlett, 1918) seven pairs of chromosomes are distinctly seen at diakinesis (Fig. 13). The behavior of these during the heterotypic metaphase is the same as in any Oenothera with pairing chromosomes.

OENOTHERA REYNOLDSII MUT. RIGIDA

Oenothera Reynoldsii mut. *rigida* shows a closed chain of twelve chromosomes and a free pair (Fig. 19) at the final prophase stages. During the heterotypic metaphase (Fig. 20) the chromosomes in the chain become attached to the spindle fibers in such a manner that the adjacent chromosomes pass to opposite poles. The chromosomes of the free pair separate and accompany the two groups of six as they pass to the poles.

SUMMARY

1. The nuclei of the sporocytes of *Oe. franciscana* race D present seven pairs of chromosomes at diakinesis. This configuration is constant in all the nuclei.
2. At the heterotypic metaphase the seven pairs of ring-shaped chromosomes are brought to the equatorial plate, from which they are distributed to the two poles in the usual manner.
3. Non-disjunction is shown to occur in 7.2 per cent of the pollen mother cells of *Oe. franciscana* race D. This presumably would give rise to fifteen chromosome forms and triploids, depending on the chromosome pairs involved.
4. Data are given to show that the frequency of the haploid from *franciscana* D is twice that from *franciscana* B.
5. A method of producing haploids at will from *franciscana* D is given.
6. A brief discussion of the genetical importance of *franciscana* D, together with its limitations, is presented.
7. Seven ring-shaped pairs of chromosomes are found in the sporocytes of *Oe. argillicola* at diakinesis. Heterotypic metaphase is regular. It is shown that the pollen of *argillicola* could very efficiently be used in artificial production of haploids.
8. A closed chain of fourteen chromosomes is observed in the final prophase stages in *Oe. Reynoldsii* and *Oe. numismatica.* At the heterotypic metaphase the chromosomes in the chain are so orientated that the alternate chromosomes are drawn to the same pole and the characteristic zigzag arrangement of the chro-

mosomes is clearly observed. The chromosome configurations discussed above explain the breeding behavior of the two species.

9. In *Oe. numismatica* mut. *robusta* a chain of fourteen chromosomes and one free chromosome are observed at the final stages of the heterotypic prophase. During the heterotypic metaphase the arrangement of the chromosomes in the chain is regularly zigzag. The free chromosome goes to one or the other of the poles. Such a chromosome configuration explains the genetical behavior of this interesting mutation.

10. *Oe. Reynoldsii* mut. *rigida* shows a closed chain of twelve chromosomes and a free pair at the final prophase stages. The behavior of the chromosomes in the chain is regularly zigzag in the heterotypic metaphase.

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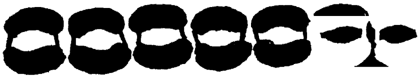
PLATE X



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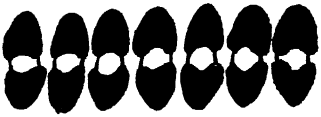

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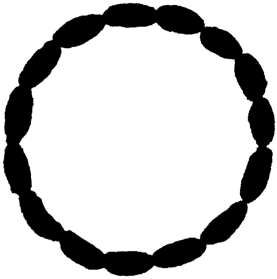

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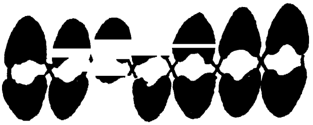

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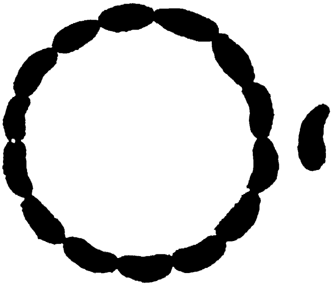

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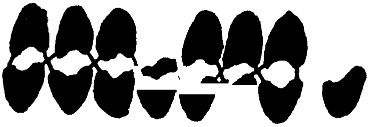

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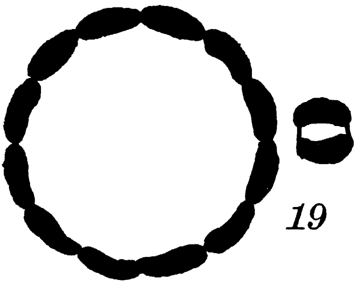

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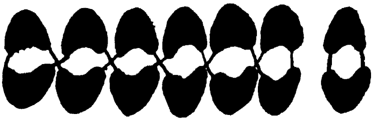

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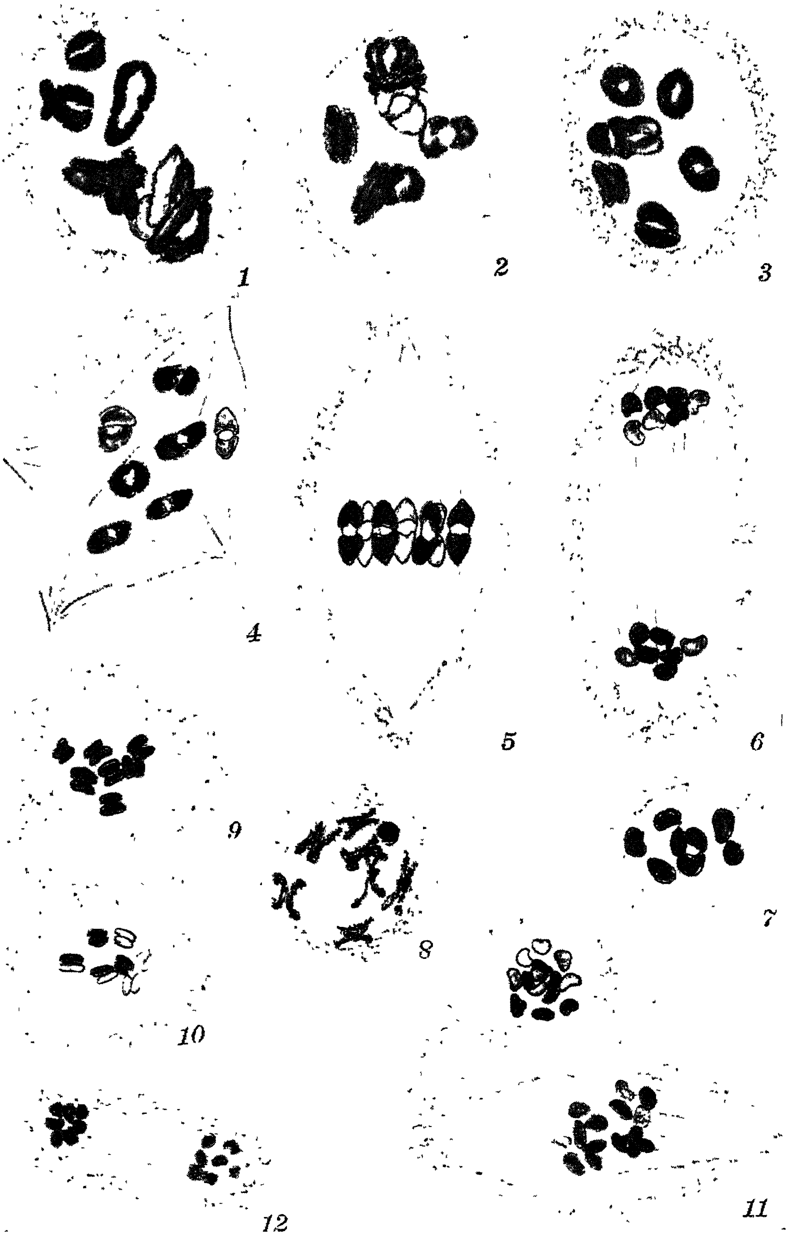
PLATE IX



EXPLANATION OF PLATES IX–X

All figures in Plate IX were sketched with the aid of a camera lucida, under a Zeiss microscope with a compensating ocular 20 × and 1.5 mm. apochromatic objective. The approximate magnification for Plate IX is 2000 diameters.

PLATE IX

FIG. 1. Mid-diakinesis showing seven pairs of chromosomes

FIGS. 2–3. Diakinesis; seven pairs of chromosomes are clearly visible

FIG. 4. Seven pairs of ring-shaped chromosomes; multipolar spindle stage

FIG. 5. Metaphase of the heterotypic division; seven pairs of ring-shaped chromosomes are distinctly seen

FIG. 6. Heterotypic anaphase

FIG. 7. Late heterotypic anaphase, with eight chromosomes, the result of non-disjunction

FIG. 8. Late interkinesis, showing seven split chromosomes

FIGS. 9–10. Homeotypic prophase. Both figures are from the same cell

FIG. 11. Homeotypic early anaphase; side view of one plate and polar view of the other. Note the fourteen chromosomes in the polar view

FIG. 12. Homeotypic telophase; only two of the four complexes are shown

PLATE X

Diagrams showing chromosome configurations in late heterotypic prophase and metaphase.

FIG. 13. Diakinesis in *Oe. argillicola* and *Oe. Reynoldsii* mut. *bilonga*

FIG. 14. Heterotypic metaphase in *argillicola* and *bilonga*

FIG. 15. Heterotypic prophase in *Oe. numismatica* and *Oe. Reynoldsii*

FIG. 16. Heterotypic metaphase in *numismatica* and *Reynoldsii*

FIG. 17. Heterotypic prophase in *Oe. numismatica* mut. *robusta*

FIG. 18. Heterotypic metaphase in mut. *robusta*

FIG. 19. Heterotypic prophase in *Oe. Reynoldsii* mut. *rigida*

FIG. 20. Heterotypic metaphase in mut. *rigida*

THE COMPARATIVE MORPHOLOGY OF GERMINATING ASCOSPORES IN CERTAIN SPECIES OF THE HYSTERIACEAE *

MARION L. LOHMAN

THE Tulasnes (12) figured in their classic volumes germinating spores for many species of fungi. The various families of Ascomycetes are well represented, but it is interesting to note that they did not include a single species of the carbonaceous, hysteriaceous fungi. Hoffmann (5) had published in 1860 his studies on spore germination in forty-eight species of fungi. He worked with a very few species of the Ascomycetes, and the Hysteriaceae are not represented. Brefeld's (3) studies on the Ascomycetes appeared a generation later. He figured germinating spores for many species. Again, the Hysteriaceae are not represented, although Brefeld had obtained certain species of the family in culture. However, certain sphaeriaceous fungi, which we now refer to the Pleosporaceae, the Massariaceae, the Cucurbitariaceae, etc., are figured, and they offer comparable spore forms.

The writer (6) recently figured two types of germ-tube development in germinating ascospores of *Glonium parvulum* (Ger.) Sacc. The conditions under which each type had developed were noted. Several species of Glonium were in culture at that time, but comparative studies on germ-tube development had to await repeated tests on spore germination in the other species. Further studies have indicated a specificity in the manner of spore germination in four species of Glonium. The knowledge of this specificity of germ-tube development in a few species indicates a possible additional aid in the interpretation of relationships within the genus, and in the case of *G. stellatum* it offers an explanation for the discrepancies to be found in specific descriptions of this fungus.

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The writer has isolated twenty-four species of carbonaceous, hysteriaceous fungi. A particular effort has been made to obtain notes and drawings of early stages of spore germination, since this family of fungi presents spores of widely diverse morphological types and the present generic conceptions within the family are determined largely on spore characters. Moreover, a number of species are delimited on spore characters alone, when the variable characters are size and septation. The common occurrence of intermediate forms — intermediate to the types upon which the descriptions are based — forces a diligent search for additional distinctions and reliable specific characters.

TYPES OF ASCOSPORE GERMINATION

De Bary (1) reviewed the early literature on spore germination and indicated that at that time writers were distinguishing between tube germination (*Schlauchkeimung*) and sprout germination (*Sprosskeimung*) in the Ascomycetes. The latter method was known to be common to certain lower Ascomycetes, namely, species of Saccharomyces and Taphrina (Exoascus), and it had been noted for the higher Ascomycetes, particularly in species of Dothidea and Nectria. It had been observed that some forms showed both types of spore germination. *Bulgaria inquinans* and *Sclerotinia* (*Peziza*) *tuberosa* were so characterized. The sprout-cell method is more or less confined to one-celled, thin-walled, hyaline spores which apparently lack definite germ pores, although there are exceptions, as in the terminal budding of the two-celled spores of Nectriae as figured by Brefeld (3), Tables 4 and 5, Figures 10, 14, 18 and 46. Brefeld also illustrated (Tab. 6, Fig. 34) sprout-cell germination in the brown muriform spores of *Fenestella vestita*. According to the observations of Brefeld, this method of germination is far more common in the higher Ascomycetes than De Bary had anticipated. The method has not as yet been observed by the writer in any of the Hysteriaceae, even under conditions in which it would most probably occur, such as old tests on germination in which the nutrient solution employed had become contaminated by bacteria.

In regard to tube germination in many-celled spores, De

Bary (p. 114) remarked: "In compound spores each merispore germinates in the same way as a single spore or has the power of doing so. It is not uncommon to see a germ-tube proceeding from almost every merispore, even where they are many in number, as in Pleospora herbarum and Cucurbitaria Laburni. Sometimes certain merispores only germinate as a rule, and if the cells are arranged in a simple row this is usually the case with one or both terminal cells of the row, as in Melogramma Bulliardii, Tul., Melanconis . . . and the stylospores of Cucurbitaria macrospora."

The generalizations drawn by De Bary hold for the Hysteriaceae. In brown or hyaline muriform spores (see discussion on *Hysterographium fraxini*, *H. vulvatum* and *Gloniopsis Gerardiana*) any cell is a potential germ cell. In phragmosporous forms the central cells are slow to germinate and perhaps in some species they very seldom function as germ cells (cf. *Hysterium pulicare*, *H. thujarum*, *H. insidens* and *Mytilidion tortile*).

FACTORS CONDITIONING GERMINATION IN THESE STUDIES

The tests for germination were made (1) in sterile distilled water, (2) on nutrient plates of Kauffman's synthetic agar medium,[1] and (3) in the nutrient solution of the medium. All of these were kept in the light at 20 to 25° C. The writer (6, p. 144) has described in some detail the procedure for preparing spore suspensions of these species in attempting to isolate them by Professor Kauffman's spray method. The other factors which enter into spore-germination work, namely, the morphological and physiological states of maturity of a given sample of spores, are not definitely known in these perennial, slowly growing fungi.

Collected material of *Hysterographium mori*, *Hysterium pulicare*, *Gloniopsis Gerardiana*, *Glonium parvulum* and *G. simulans* germinated just as readily one to two years after the time of collection as when first brought from the field. Certain other species required an alternate wetting and drying for several days as a stimulus to ready germination. With this stimulus three-year-old spores of *G. stellatum* could be germinated within forty-eight to seventy-two hours. *Hysterographium vulvatum* material required a twelve- to twenty-four hour alternation of wetting and drying for five to eight or even ten days before a high percentage of germination could be obtained. The method did not stimulate germination in the material of the two collections of *H. fraxini*.[2] It was discovered that the subjection of these spores to freezing temperatures, after a short wetting, would yield a high percentage of germination within thirty-six to forty-eight hours.

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[1] To the liter: maltose 5.0 gr., peptone 0.1 gr., $MgSO_4$ 0.5 gr., KH_2PO_4 0.25 gr., $Ca(NO_3)_2$ 0.1 gr. and agar 15 gr.

Tests involving *Glonium parvulum*, *G. simulans*, *Hysterographium mori*, *Hysterium pulicare* and *Gloniopsis Gerardiana* were made at 10, 20 and 25° C. on nutrient agar plates and in sterile distilled water, and it was determined from these tests that the differences in temperature produce no appreciable differences in the morphology of the germ tube in a given species.

THE DEVELOPMENT OF THE GERM TUBE IN THE VARIOUS SPORE FORMS

In species with muriform spores

The most common species of the family in the vicinity of Ann Arbor are *Gloniopsis Gerardiana* Sacc.,[3] *Hysterographium mori* (Schw.) Rehm and *H. vulvatum* (Schw.) Rehm. Germination has been studied for these species and for *H. Lesquereuxii* Duby, *H. fraxini* (Fr.) De Not., *H. formosum* (Cooke) Sacc., *H. kansense* E. & E., an undescribed species of Hysterographium similar to *H. pachyascum* Berl., and for an undescribed species of Gloniopsis. The spores of these species germinate by slender, hyaline tubes which are uniform in their diameter. The tubes average 2 μ in diameter, usually somewhat thicker in the large-spored *H. vulvatum*, and they become septate and develop lateral branches within eighteen to twenty-four hours after emergence. Germinating spores of a few of the species are figured on Plate XI. Subsequent growth results in the formation of typical mycelial hyphae.

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[2] Obtained from the Manitoba Agricultural College grounds through the kindness of Professor G. R. Bisby.

[3] Since the writer is using here von Höhnel's conception of the family (see *Ann. Mycol.*, 16 : 145–154. 1918), his genera are retained. In *The North American Pyrenomycetes*, by Ellis and Everhart, *G. Gerardiana* Sacc. is found in the synonymy of *Hysterographium gloniopsis* (Ger.) E. & E.

Spores of all the morphological forms or varieties of *H. mori* germinate by two to eight or ten tubes and the tubes are similar in all respects to those figured on Plate XI for *H. kansense* (Figs. 1–3), *H. formosum* (Fig. 6) and *Gloniopsis Gerardiana* (Figs. 7–8).

The illustrations referred to represent early stages in germ-tube development. These species also show a number of tubes on the second or third day. As many as sixteen tubes have been counted for single spores of *H. kansense* and *H. formosum.* In the latter species maximum germ-tube development occurred at 10° C., for low temperatures favor most vigorous vegetative growth. A number of isolations retained at 20 to 25° C. did not develop mycelia, and when transfers were made from vigorously growing cultures at 10° C. and the subcultures held at the higher temperatures, only a sclerotic transformation of the mycelium occurred; the cultures showed no radial increase after eight weeks of growth.

In general, the brown spores (species of Hysterographium) retained their color on germination until concealed by the developing hyphae. The hyaline spores of *G. Gerardiana* and an undescribed species of that genus remain hyaline during germination, even when placed in direct sunlight for several days.

The spores of *H. fraxini* (Pl. XI, Fig. 4) and *H. vulvatum* (Pl. XI, Fig. 5) present certain peculiarities in their germination. Both these species possess large, merenchymatic spores. Mature spores of *H. fraxini* measure 35–45 × 12–16 μ, but those of *H. vulvatum* measure (45) 50–58 (65) × (12) 14–18 (22) μ. The swelling which accompanies germination is considerable in these two species. *H. fraxini* spores become 45–58 × 16–20 μ; those of *H. vulvatum,* 55–70 × 20–26 μ. A loss of the deep brown or opaque condition accompanies this swelling and the true cellular structure of the resulting subhyaline to yellow-brown spores is not easily determined. The merenchymatic condition is lost in the spores of each and the distinct cross and longitudinal markings are fewer. This is illustrated in Figure 5, in which the dotted lines represent the spore markings previous to germination. The true internal structure of these spores should be determined by histological methods. In this connection, observations on the sparingly muriform spores of *H. mori* and *G. Gerardiana*, in vertical or tilted positions on agar plates, indicated that each centrum is usually two- to three-parted by as many radial plates and that each division is a potential germ cell.

Although *H. fraxini* and *H. vulvatum* are both large-spored species of a somewhat similar habitat, they are not at all alike in the gross morphology of the hysterothecium, in vegetative cultural characters, or in the manner of germ-tube development. *H. fraxini* is distinct in the abrupt branching, early septation and peculiar coiling of its germination hyphae (Pl. XI, Fig. 4). About the third day after emergence hyphal tips cease to coil and they grow radially outward in rather straight courses. The early coiling is probably to be associated with a tremendous swelling and slow solution of the firm, mucilaginous coat with which the spores of this species are provided. In the material of this species, hyaline to yellowish, 3- to 5-septate, morphologically immature spores without longitudinal divisions germinated as readily as the many-celled, brown spores.

In phragmosporous forms

The development of the germ tube has been studied for *Mytilidion tortile* (Schw.) Sacc., *M. laeviusculum* (Karst.) Sacc., *M. decipiens* (Karst.) Sacc., an undescribed species of Mytilidion common at Ann Arbor on resinous knots of *Larix laricina* (Du Roi) Koch, *Hysterium thujarum* C. & P., *H. pulicare* Pers. ex Fr., *H. angustatum* Alb. & Schw., *H. insidens* Schw. and *Lophium mytilinum* (Pers.) Fr.[4] Similar observations have been made on two species of Hysteropatella,[5] namely, *H. Prostii* (Duby) Rehm (*Hysterium Prostii* Duby) and *H. clavispora* (Peck) Seaver (*Tryblidium clavaesporum* Peck (8; see also 11) and *Tryblidiella clavispora* (Peck) Berl. & Vogl. (2; see also 10).

[4] Scolecosporae in the volumes of Saccardo's *Syll. Fung.*

[5] Hysteriineae Schröt. in the sense of Rehm. See *Ber. d. bayer. bot. Ges. in München*, 13 (1912): 102–120.

Germinating spores of seven of the foregoing species are figured on Plate XII. The figures illustrate that mature spores of *Mytilidion tortile* (Figs. 1–3), *M. decipiens* (Fig. 4), *Hysterium insidens* (Figs. 9, 11) and *H. pulicare* (Figs. 13, 15) germinate by a narrow uniform tube which becomes septate after considerable elongation of the tube. *H. angustatum* and the two species of Hysteropatella show a similar type of germ-tube development. The septation of the tubes in the foregoing species is not accompanied by an abrupt swelling of the proximal portion of the two to five cells nearest the spore. The latter condition characterizes germinating spores of *H. thujarum* (Figs. 6–8), particularly immature spores, and immature spores of *H. insidens* (Fig. 10) and *H. pulicare* (Fig. 14). In these species the presence of the swollen cells in the germ tubes has not been correlated with conditions of nutrition or temperature and it undoubtedly is the expression of certain potentialities in the spores of these species.

Germinating spores of *Mytilidion laeviusculum* (Fig. 5) show a type of germ hypha which is intermediate between this and the straight, unconstricted, tardily septate type. The basal portion of the first cell is ordinarily considerably swollen, but the more distal cells of the tube are of a uniform diameter. Minks (7) noted the same condition in this fungus and favored accepting the two-celled spore as the mature spore, regarding further cell formation as a continued, slow germination. The spores are a clear, yellow brown in the central cells, but terminal cells in 3- to 4-septate spores are yellowish hyaline. Spores retained within the asci are typically 3-septate and further septation usually occurs in old spores retained within the epithecium.

In the phragmosporous species the terminal cells are the first to germinate. When germination does occur in the central cells it follows twenty-four to forty-eight hours later. In the 7- to 9-septate spores of *H. insidens* typical germination is by a single tube from a terminal or penultimate cell of one or both ends of the spore. The other cells probably function as storage cells. Their germination is very uncommon and only a single spore was observed in which the swollen cell had germinated. In contrast to these spores, any cell of the filiform *Lophium mytilinum* spores (Pl. XII, Fig. 12) is a potential germ cell and may germinate first. The terminal cells invariably germinate. The germ tubes grow 100 to 200 μ before the faint cross septa appear and then they develop sparse, lateral branches. The hyphae develop with a uniform diameter, and growth is rapid as compared with species of Hysterium, Hysterographium and Mytilidion.

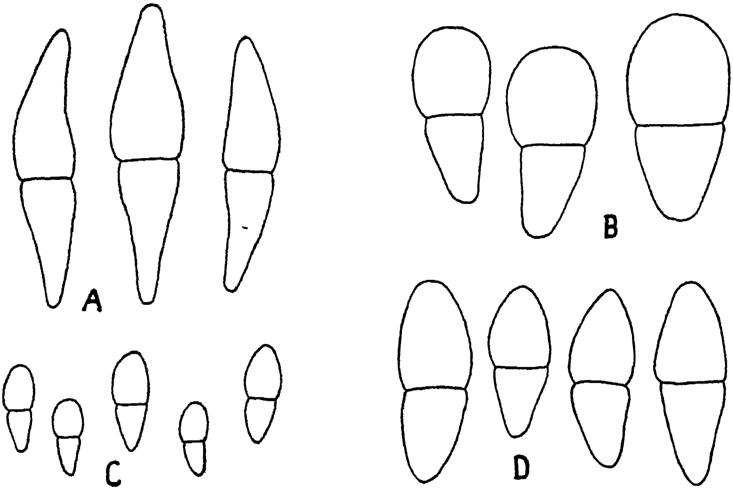

FIG. 1. Ascospores of four species of Glonium, drawn to a common scale. *A*, *G. stellatum* Muhl.; *B*, *G. lineare* (Fr.) De Not.; *C*, *G. parvulum* (Ger.) Sacc.; *D*, *G. simulans* Ger. The approximate magnification is 1650 diameters

In certain species of the genus Glonium

Four species of Glonium have been studied by the writer. Of these, *G. parvulum* (Ger.) Sacc. is distinct in its short hysterothecia, measuring 0.25–0.4 (0.5) × 0.15–0.2 mm., and small spores, measuring 6–8 × 2.5–3 μ; *G. simulans* Ger., in its larger, oblong hysterothecia with rounded ends and elliptical, larger spores; *G. lineare* (Fr.) De Not., in its elongate, scarcely erumpent, flat hysterothecia and oblong spores; and *G. stellatum* Muhl., in its stellately branched, composite fructification and large, ellipticfusiform spores. Figure 1 shows the spores of these species drawn to a common scale. The striking difference in contour between the spores of *G. lineare* and *G. simulans* (see Figs. 1*B* and *D*) was not sufficiently emphasized by Ellis (4). Consequently, on the basis of the descriptions given by Ellis, confusion or misinterpretation of material is likely to result.

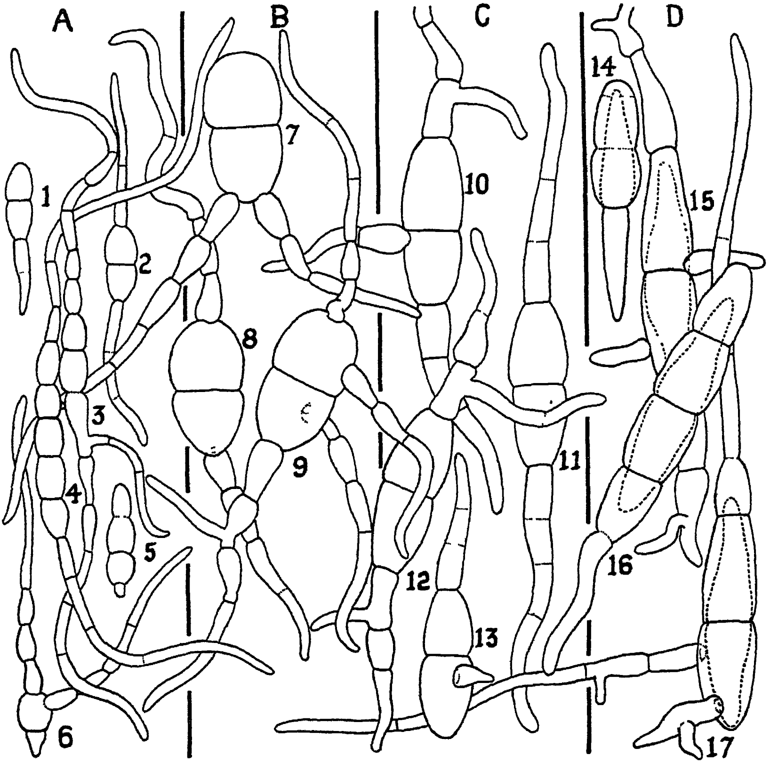

Fig. 2. Various stages of germ-tube development in four species of Glonium, drawn to a common scale. *A*, *G. parvulum* (Ger.) Sacc.; *B*, *G. lineare* (Fr.) De Not.; *C*, *G. simulans* Ger.; *D*, *G. stellatum* Muhl. (the dotted outline represents the relative size and form of the ungerminated spore). The magnification is approximately 1300 diameters

Germ tubes of *G. parvulum* show, when developing on a nutrient agar medium or in the solution of the medium, a series of swollen basal cells scarcely distinguishable from the two original spore cells (Figs. 2*A*, 3–4). This condition occurs occasionally in distilled water and when it does the abrupt swelling of the proximal portion of the cells resembles the condition shown in *A* 6, although most germ tubes in distilled water are of the type illustrated in *A* 2. The formation of two germ tubes (*A* 6) in the upper and often larger cell is uncommon.

Germ tubes of *G. lineare* (Fig. 2*B*) develop a short series of basally swollen cells in distilled water as well as on nutrient agar plates. Though a second germ tube from any one of the cells in spores of the other three species is very uncommon, it occurs in about 40 per cent of the spores of this species. In a count of 250 germinating spores, from six microscopic fields chosen at random, representing two samples of spores from each of three hysterothecia, it was determined that the average spore had 2.4 germ tubes. The tubes were evenly distributed between the two cells, each cell averaging 1.2 tubes. Whenever tested, the material of this species showed a high percentage of germination.

G. simulans (Fig. 2*C*) is characterized by germ tubes of uniform diameter (*C* 10–11), which become close-septate within twenty-four hours. The condition shown in *C* 12 was seen occasionally on the nutrient agar medium. In its germ-tube morphology the species is decidedly intermediate between *G. parvulum* and *G. stellatum.*

Fig. 2*D* 16 illustrates a typical early stage of spore germination in *G. stellatum,* showing that the germ tube is merely an elongation of one of the cells of the spore to produce a hypha of equal diameter. A second, lateral, tube, as shown in 15 and 17, is uncommon. In spores with lateral tubes a cross septum was not observed between the central septum and the terminal germ tube. But in typical germination the appearance of a cross septum a short distance behind the end of the original spore cell is the usual circumstance. This is well illustrated in *D* 14 and 16.

This manner of germination has given rise to statements in the literature to the effect that the spores of this species are two-to four-celled. Petrak (9, No. 226, "Über die Gattung Glonium Muhl.") described the spores as two- to more-celled. He based his studies upon material collected in Kentucky and sent to him by the late Professor Bruce Fink. A large portion of that same Kentucky collection is in the herbarium of the University of Michigan, and I find it to be typical *G. stellatum* Muhl., with hyaline, didymous spores.

SUMMARY

1. The germination of the ascospores has been studied in twenty-one described species and in three undescribed species of the Hysteriaceae. The development of the germ tubes in (1) sterile distilled water, (2) on a nutrient agar medium, and (3) in the nutrient solution of that medium, at 20 to 25° C., is described for the twenty-four species, and germinating ascospores are figured for sixteen of those species.

2. An alternate wetting and drying stimulated germination in spores of all the species with the exception of *Hysterographium fraxini* (Fr.) De Not.

3. Concerning the germ tubes, two types of development are recognized: (1) a germ hypha of uniform diameter, typical for species with muriform spores (two species of Gloniopsis and seven species of Hysterographium), for *Lophium mytilinum* (Pers.) Fr., *Mytilidion tortile* (Schw.) Sacc., *M. decipiens* (Karst.) Sacc., *Hysterium pulicare* Pers. ex Fr., *H. angustatum* Alb. & Schw., *H. insidens* Schw., *Hysteropatella Prostii* (Duby) Rehm and *H. clavispora* (Peck) Seaver; (2) a germ hypha with the first few basal cells abruptly swollen in their proximal portions, typical for *Glonium parvulum* (Ger.) Sacc., *G. lineare* (Fr.) De Not., *Hysterium thujarum* C. & P., and for immature spores of *H. insidens* Schw. and *H. pulicare* Pers. ex Fr.

4. *Mytilidion laeviusculum* (Karst.) Sacc., *Glonium simulans* Ger., *G. stellatum* Muhl. and *Hysterographium fraxini* (Fr.) De Not. show special modifications of the first type.

5. Germinating spores of *Glonium lineare* average more germ tubes than the germinating spores of the other species of Glonium included in this study.

6. *Glonium simulans* is intermediate, in respect to its germination, between *G. parvulum* and *G. stellatum.*
7. The material of *Hysterographium fraxini* proved to be exceptional in that freezing temperatures were required to stimulate germination and in that the germ hyphae coiled in a peculiar manner and became branched and septate comparatively early.
8. The germ tubes of *G. stellatum* ascospores are merely elongations of the two cells of the spore. The tubes are broad and become septate early, the first septum appearing behind the end of the original spore cell. This explains the discrepancies pertaining to the number of cells in mature spores that occur in specific descriptions of this fungus.
9. In species with muriform spores and in the filamentous spores of *Lophium mytilinum* any cell of the spore is a potential germ cell.
10. In most of the phragmosporous forms the central cells of the spores seldom germinate.
11. A shedding or breaking of the exosporium upon germination has not been observed in any of the species studied.
12. In the species studied the germ tubes developed immediately into hyphal threads. Sprout-cells or secondary spore stages were not formed on these early hyphae.
13. The germ tubes of *Hysterographium formosum* (Cooke) Sacc. did not develop mycelia at 20 to 25° C., but they did initiate vigorous mycelial growth at 10° C.

This study was made in the Department of Botany of the University of Michigan. It represents a small part of the writer's researches on the biology of hysteriaceous fungi — studies which were begun in the fall of 1928 under the supervision of Professor C. H. Kauffman, who emphasized the need for information of this nature in those families of the Ascomycetes in which relationships are not satisfactorily understood. Acknowledgments are due to Professor E. B. Mains for suggesting the recording of this information as a unit, and for a critical reading of the manuscript.

UNIVERSITY OF MICHIGAN

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EXPLANATION OF PLATES XI AND XII

The illustrations are based upon the observation of numerous germinating spores in distilled water and on nutrient agar plates at 20 to 25° C. The drawings were made to a common scale and the magnification is approximately 1300 diameters.

PLATE XI

Hysteriaceae—Dictyosporae

Hysterographium kansense E. & E.

FIG. 1. Typical germination at 24 hours.

FIGS. 2–3. Germination within 24 hours by terminal and central cells. This was not a common occurrence. At 48 to 72 hours the spores of this species averaged twelve to sixteen germ tubes.

Hysterographium fraxini (Fr.) De Not.

FIG. 4. Germ-tube development at 48 hours. The coiling, early septation and branching proved to be the characteristic manner of spore germination.

Hysterographium vulvatum (Schw.) Rehm

FIG. 5. Early stages in germ-tube development. Apparently any cell is a potential germ cell. At 72 hours as many as twenty-four germ tubes were observed for a single spore.

Hysterographium formosum (Cooke) Sacc.

FIG. 6. Germination within 24 hours. Spores which were isolated when in this early stage of germination and retained at 20 to 25° C. did not develop mycelia (see discussion in text).

Gloniopsis Gerardiana Sacc.

FIGS. 7–8. Germination within 24 to 48 hours. The terminal cells are ordinarily the first to germinate.

PLATE XII

Hysteriaceae—Phragmosporae (Fig. 12 excepted)

Mytilidion tortile (Schw.) Sacc.

The mature ascospore is ordinarily four-celled.

FIGS. 1–2. Typical germination within 24 hours.

FIG. 3. Germination of one of the central cells. This type of germination was observed in a very few spores after 48 to 72 hours.

Mytilidion decipiens (Karst.) Sacc.

The mature ascospore is four-celled.

FIG. 4. Typical germination is by one or two tubes from the yellow terminal cells.

Mytilidion laeviusculum (Karst.) Sacc.

The mature ascospores are four- or five-celled.

FIG. 5. Germ-tube development 48 hours after emergence from the terminal cells in a five-celled spore. The germination of central cells was not observed.

Hysterium thujarum C. & P.

The mature ascospore is ordinarily six-celled.

FIGS. 6–7. Typical germination within 24 to 48 hours. At 48 to 72 hours a very few spores were observed in which one or two of the central cells had developed germ tubes.

FIG. 8. A germinating, 3-septate, hyaline spore. The germination of numerous, hyaline, 1- to 3-septate, morphologically immature spores was observed in this species.

Hysterium insidens Schw.

The septation of spores in this species is variable. Brown spores may be 5- to 9- and, occasionally, 10-septate.

FIGS. 9–11. Typical germination is by a single tube from a terminal or penultimate cell of one or both ends of the spore. The germination of central cells proved to be extremely rare, and in only one case out of hundreds germination had occurred in the swollen cell.

Lophium mytilinum (Pers.) Fr.
(Scolecosporae)

The ascospores are 15- to 20-septate. A considerable swelling of the cells precedes the development of germ tubes.

FIG. 12. Typical germination within 18 to 24 hours.

Hysterium pulicare Pers. ex Fr.

The ascospores are ordinarily four-celled. The terminal cells may be hyaline, yellow or clear-brown.

FIG. 13. A germinating spore in median, longitudinal sectional view, illustrating the dense, oily-granular protoplasmic content which is characteristic of germinating spores and young mycelial filaments in this species.

FIG. 14. The manner of germ-tube development in hyaline, morphologically immature spores. Note the abrupt swelling in proximal portions of germ-tube cells.

FIG. 15. A condition found in approximately 5 per cent of the germinating spores at 48 to 72 hours. In such spores the hyphae were 200 to 250 μ in length, close-septate, and becoming branched at the third or fourth cell from the point of emergence.

PLATE XI

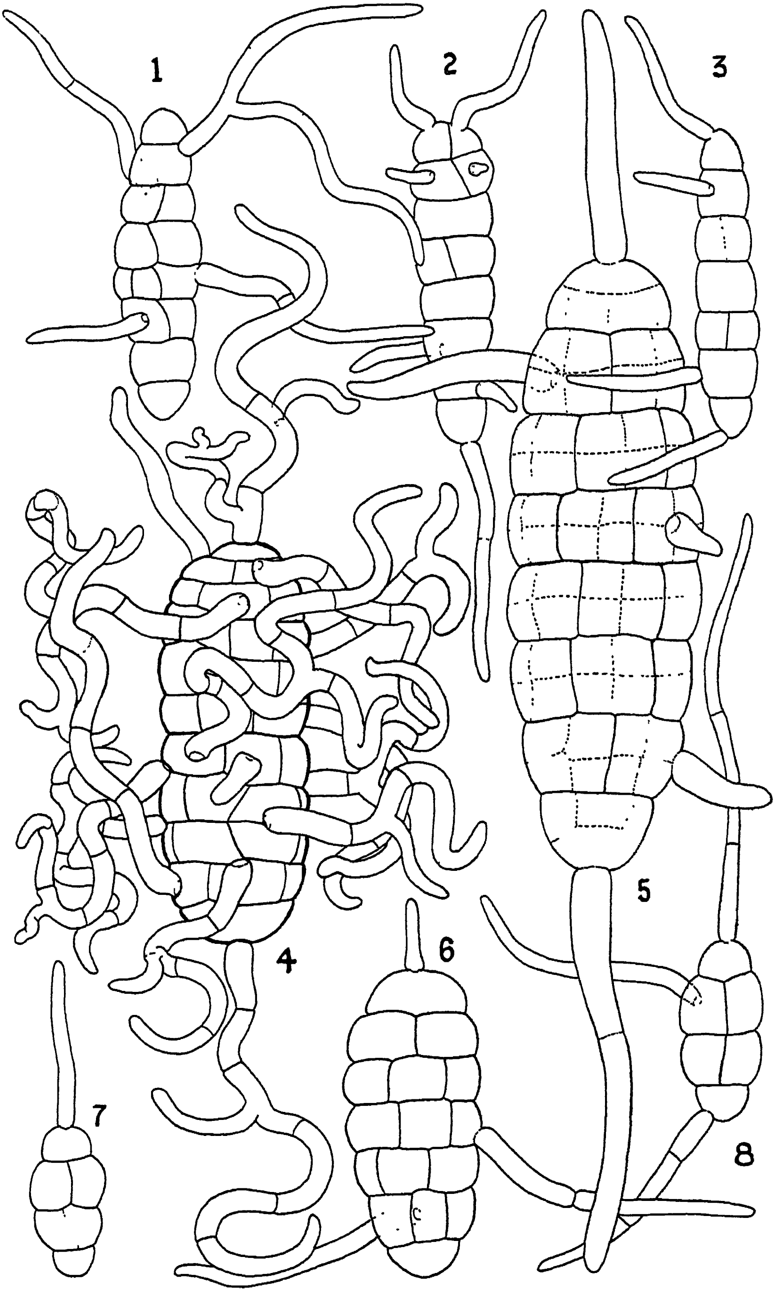
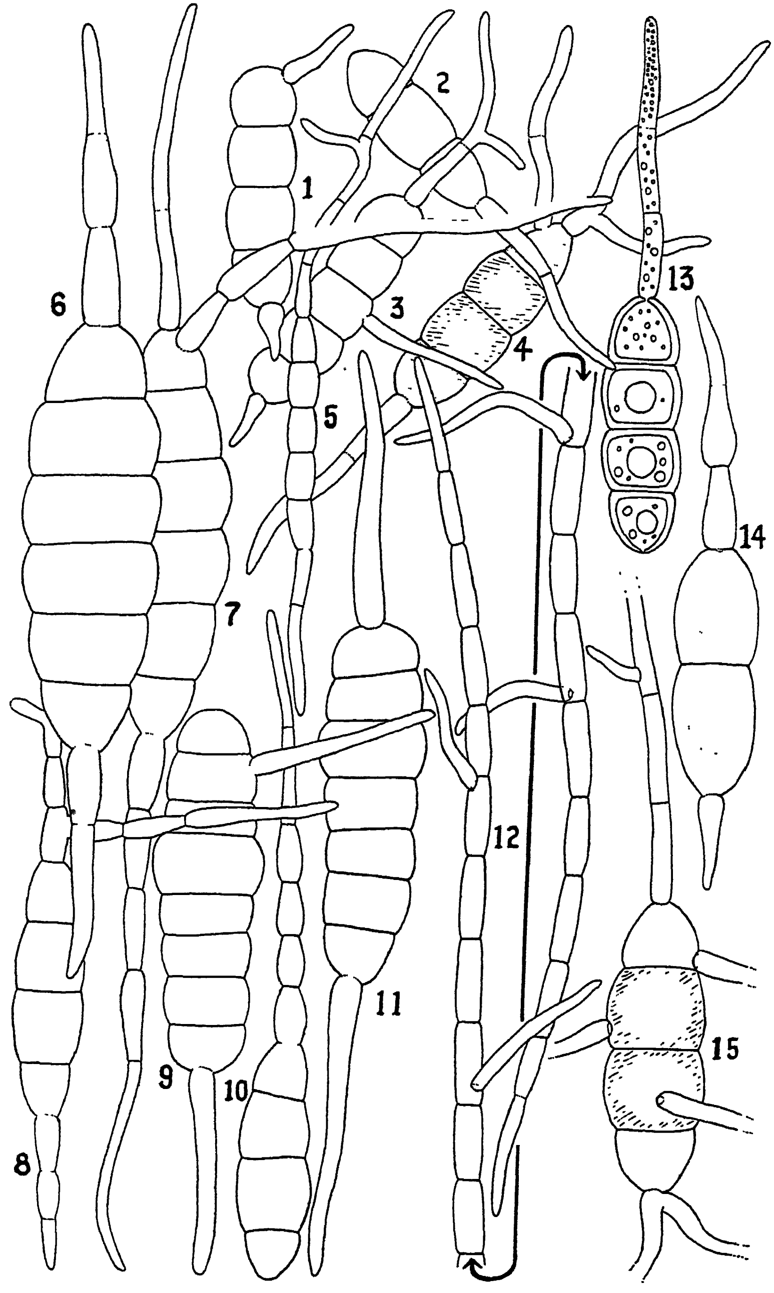


PLATE XII



THE DESMIDS OF MICHIGAN, WITH PARTICULAR REFERENCE TO THE DOUGLAS LAKE REGION *

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AND

ALMA B. ACKLEY

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THIS paper comprises a list of all the desmids (Desmidiales) known to occur in the State of Michigan, together with notes regarding their distribution and habitat relations. Previous publications dealing specifically with the algae of Michigan, either as a whole or in part, have been few, and the only paper that has heretofore attempted to cover the entire state is that of Transeau (9), who records a total of 226 species and varieties.

For the desmids in particular, only six publications are known which contain definite citations of Michigan specimens. The earliest of these is by Campbell (3), who includes 41 species in a list of 86 algae, most of them "collected during a month's visit at Grosse Isle, near the mouth of the Detroit River, in the summer of 1885." Two papers by Johnson (4) on "some new and rare desmids from the United States" list 28 additional species for Michigan; and the studies of W. and G. S. West (10), based chiefly upon the collections and notes of Johnson examined after his death, contain references to 28 Michigan desmids. Transeau's list (9) includes 65 species. The junior author, in a recent paper (1), has described 2 new desmid forms on the basis of Michigan material.

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* Contribution from the University of Michigan Biological Station, the Osborn Botanical Laboratory, and the College of the City of Detroit.

The present contribution is based very largely on material collected in the course of a general survey of the algae of Michigan. This work was begun in 1922 at the University of Michigan Biological Station, on Douglas Lake, where intensive collecting was done by both authors during that and the two succeeding summers. Subsequently, in addition to continued observations in the Douglas Lake region by the senior author, the junior author has made extensive collections throughout the state. During the course of three summers she visited all the counties in the Northern Peninsula and most of those in the Southern, and has also carried on intensive investigations throughout the year in the country around Detroit, Ann Arbor and Lansing. The collections thus acquired have been supplemented by those of the late Dr. Jan Metzelaar, of the Conservation Department of Michigan, and of Professor T. L. Hankinson, of Michigan State Normal College. All together, more than 1,700 lots of algae have been examined. Most of the collections made by both authors are preserved in the herbarium of the junior author.

For the identification or verification of the majority of the desmids here recorded for the Douglas Lake Region, the authors are indebted to Dr. Nellie Carter, of East London College, England, who examined practically all the material collected during 1923 and 1924.

Most of the species credited to Michigan in earlier publications have been found during the course of the present survey and, for the sake of completeness, those which have not been rediscovered are also listed in the present article. The list here given represents, therefore, a summary of all the desmids known to occur, or recorded as occurring, within the boundaries of the state.

DISTRIBUTION OF MICHIGAN DESMIDS IN RELATION TO GEOLOGICAL AND OTHER ENVIRONMENTAL INFLUENCES

General features of Michigan geography and geology

The State of Michigan, in the main, comprises two peninsulas, the Upper or Northern and the Lower or Southern, both of which are bounded to a large extent by the Great Lakes or their connecting waterways. The Northern Peninsula is relatively narrow, about 330 miles long with an average width of perhaps 50 miles, and lies with the long axis oriented approximately east and west. The Southern Peninsula is shorter and broader, about 280 miles long with an average width of about 165 miles, and lies with the long axis roughly oriented north and south.

In the Northern Peninsula the western part consists of an ancient, uplifted peneplain which is largely underlain by rocks of pre-Paleozoic age. This western Highland region averages approximately a thousand feet higher than the eastern Lowland region, which is underlain by Paleozoic rocks — Cambrian, Ordovician and Silurian. Throughout both areas most of the bedrock is covered by deposits of glacial drift of varying thickness. The Southern Peninsula increases in elevation chiefly from south to north, being but little above the level of the adjoining Great Lakes toward the south and rising to elevations of from 300 to 500 feet above them (or from 1,100 to 1,300 above sea level) toward the north. Most of the underlying rocks here are of Carboniferous or Devonian age and, as in the Northern Peninsula, are largely covered over by glacial drift.

Michigan conditions unusually favorable for desmids

Both in the Southern Peninsula, especially northward, and in the Northern Peninsula the country abounds in small lakes and ponds of every description; in marshes and open or wooded bogs and swamps; in streams and creeks, both swift and slow; in pools and water-filled ditches of varying size and permanence. In short, the State of Michigan, with its wide assortment of aquatic and semiaquatic habitats, presents conditions which make it an unusually fertile collecting ground for fresh-water algae. Particularly do conditions seem favorable to desmids, of which no fewer than 370 species and named varieties or forms are listed in this paper as having been collected here. As compared with other areas of similar size, Michigan would doubtless have been characterized by W. and G. S. West (11) as having a "rich" desmid flora. This designation is applied by them not "to a mere abundance of desmids, or even to the occurrence of a great quantity of 30 or 40 species, but only to those areas in which 150 to 200 (or even 300) species can be found in more or less abundance, including many of the rare species with a restricted distribution."

Variations in desmid "richness" in relation primarily to geological conditions

Various explanations have been advanced in attempting to account for the great disparity so frequently observed in the richness of the desmid floras between different geographical regions, as well as between different localities within the same general region. In discussing the greater richness of the desmid plankton in the lake areas of western as compared with eastern sections of the British Isles, W. and G. S. West (11) quote Sir John Murray as having pointed out that the former are characterized by greater rainfall. "Such conditions," they write, "naturally result in wet mossy hill-sides, with numerous bogs," and, in consequence, there is "much peaty water, rich in humic and other organic acids," which furnishes "all the requirements for the prolific growth of desmids." They note, however, that the presence of such conditions, in itself, does not necessarily result in desmid "richness"; it may be conducive to the luxuriant quantitative development of certain forms, but not necessarily to the development of a flora rich in species. They themselves maintain that "some factor, other than the mere abundance of rainfall and presence of ideal habitats, has a profound influence on the distribution of desmids." They emphasize the fact that, for the British Isles, the areas of maximum species development coincide very accurately, in their geographical distribution, with those underlain by the more ancient geological formations, namely, the pre-Cambrian and the older Paleozoic; and they advance the general hypothesis that "the really rich desmid floras are found only in those areas which combine the most suitable habitats with a drainage water derived from geological formations older than the Carboniferous." They further infer that the influence of these various geological formations on desmid distribution is expressed through their effect on the chemical composition of the drainage water in the areas concerned, and suggest the relative abundance of lime as a possible determining factor.

Absence of lime, as "the main condition on which the occurrence of Desmidiaceae depends," is stressed by Strøm (6), who elsewhere (8) states that "the majority of desmids are calciphobe." Pearsall (5) maintains that desmids are best developed in waters which are "very poor in calcium and with a high proportion of potassium and sodium." Both Strøm and Pearsall recognize that the structure of the subjacent geological formations may be of importance in relation to desmid distribution, but only indirectly.

The geological conditions of Michigan, at first thought, would seem to offer an unusual opportunity to compare the desmid floras of aquatic habitats overlying geological formations of different ages. The western half of the Northern Peninsula, as already noted, is largely underlain by pre-Paleozoic formations, the eastern half by Paleozoic. In both areas these rock formations are covered by deposits of glacial drift, of about the same character and thickness. Temperature, precipitation and atmospheric humidity are essentially the same throughout. And yet an analysis of the two desmid floras would indicate that the western section, with its older and mostly lime-poor geological formations, contains only about 9 per cent of the total number of desmids recorded for the state, whereas the eastern section, with its younger and mostly lime-rich formations, contains 14 per cent of the total. Even more surprising would appear to be the fact that no less than 94 per cent of the total desmid species known for Michigan have been collected in the Southern Peninsula, which is geologically the youngest part of the state and a region where the underlying rock formations are predominantly rich in lime.

The explanation for this apparent lack of correlation between desmid richness and geological conditions is to be found partly in the fact that the surface waters of the state, for the most part, are influenced only to a minor degree by the nature of the underlying rock. For not only are these rocks nearly everywhere covered over by a thick mantle of glacial drift, but the topography, particularly in those parts of the state which are underlain by the younger geological formations and in which it might be anticipated that the inhibitory influence of lime-containing waters on desmid development would be most pronounced, is in large measure comparatively flat or rolling, with the result that the drainage is mostly superficial. The majority of the streams in these sections have their sources in swamps and many of them flow for long distances through boggy or poorly drained country. Springs and, in general, all seepage waters of deep-seated origin are scarce.

Desmid distribution in relation to temperature

Ground-water temperatures often run lower in bogs than in ordinary swamps, but it is very doubtful whether this difference is sufficiently pronounced to be of value as an explanation for the relative abundance of desmids in bogs. As a matter of fact, not only do bog temperatures fluctuate markedly from time to time, but the variation in temperature during the course of a single day, in a particular bog, may be far greater than any average difference between that bog and other types of swamp. Thus far, in the course of the present survey and within the range of ordinary lake, stream and ground-water temperatures, it has not been possible to establish any definite correlation between desmid abundance and temperature.

Desmid distribution in relation to hydrogen-ion concentration

During recent years many studies have been made of soil acidity in relation to plant distribution, and the precise measurement of specific acidity and alkalinity in terms of hydrogen-ion (pH) concentration has been rendered fairly simple by the development of compact field "indicator sets." Comparatively few observations have as yet been published, however, on the acidity-alkalinity relations of the desmids. Pearsall (5) determined pH values for "desmid lakes" and "diatom lakes" in England, but found little difference between the two; in all tests the water proved to be very nearly neutral, giving a reaction of pH 7.2–7.6. He concludes, therefore, that desmid lakes are typically "neutral or slightly alkaline in reaction." Strøm (8), on the other hand, finds that in Norway the acid bogs contain a far richer desmid population than any other type of habitat, in both quality and quantity. He estimates, in fact, that approximately 70 per cent of the native Norwegian species are practically restricted to bogs. The comparative richness of the desmid flora along the Atlantic Coastal Plain of the United States seems to be correlated, according to Brown (2), with the widespread occurrence in this region of acid sand and clay soils. In her opinion the presence of slightly acid waters is "more important than temperature or underlying geological formations in limiting the occurrence and distribution of desmids."

The relation between the abundance of desmid species and the hydrogen-ion concentration of the water in various types of aquatic habitat in Michigan is indicated in Table I, in which the pH values are based on a large number of field tests made by the junior author. These tables show that the bogs possess by far the richest desmid flora of any habitat — richest both in total number of species and in the number restricted to a particular type of habitat.

TABLE I

THE pH VALUES FOR VARIOUS TYPES OF AQUATIC HABITATS IN MICHIGAN, TOGETHER WITH DISTRIBUTION OF DESMID SPECIES IN DIFFERENT HABITATS

	pH values			Number of species		
	Max.	Min.	Av.	Found only in one particular habitat	Found in other habitats as well	Total
Lake.........	9.8	6.6	8.0	28	72	100
Open pool.....	9.6	6.4	8.0	18	69	87
Slow stream...	8.5	6.8	7.9	7	32	39
Rapid stream..	8.2	6.8	7.8	3	14	17
Ditch.........	8.6	6.6	7.8	4	19	21
Cold brook....	8.4	6.4	7.5	2	6	8
Open marsh...	7.8	7.5	7.6	2	4	6
Wooded swamp	8.2	6.7	7.5	2	7	9
Sphagnum bog.	6.8	3.4	4.8	113	102	215

The quantitative luxuriance of desmids also is far greater in bogs than elsewhere. It is worthy of note, in this connection, that the average pH value for the bogs of Michigan, namely, 4.8, is nearly identical with the mean of pH 4.5 found by Strøm for the peaty moors of Norway.

The table brings out the additional fact that the subalkaline lake waters, at the opposite end of the pH series from the bogs, also possess a moderately rich desmid flora, second only to that of the bogs. That the desmid flora should be richer in habitats at the two extremes of the pH series than in any of the intervening types of habitat would suggest the soundness of Strøm's (7) observation that, although "the specific reaction of the water is a potential factor in determining the character" of the desmid flora, this factor "must always be regarded in conjunction with the other physical and chemical properties of the medium."

In conclusion, it is not without interest that the center of distribution of desmid species for the State of Michigan apparently coincides with that of greatest bog development, the richest growths — in both variety and quantity — having been observed in the Douglas Lake region, near the northern end of the Southern Peninsula.

LIST OF SPECIES

In the detailed list which follows, information is given regarding habitat, months of occurrence and distribution by counties, so far as the facts are available from first-hand observations. In citing the localities for species collected by the authors, or for species represented in collections examined by them, Cheboygan and Emmet counties have been placed first, as comprising the "Douglas Lake region"; the other counties follow, arranged in alphabetical order. For species known from published records only, county localities are given, together with citations from the literature, but no additional data. Species for which some or all of the Michigan material has been determined or verified by Dr. Carter are indicated by an asterisk (*).

DESMIDIALES

GONATOZYGACEAE

GONATOZYGON ACULEATUM Hastings forma MINOR W. & G. S. West. — Bog pools; Aug.; Cheboygan.

GONATOZYGON MONOTAENIUM De Bary. — Macomb (10).

MESOTAENIACEAE

MESOTAENIUM MACROCOCCUM (Kütz.) Roy & Biss. — Washtenaw (10).

NETRIUM DIGITUS (Ehrenb.) Itzigs. & Rothe.* — Acid lake, beach pools, creek, setback from creek and bogs; July–Aug.; Cheboygan, Emmet and Chippewa; also Mackinac (9).

NETRIUM NAEGELII (Bréb.) W. & G. S. West. — Bog pools; Aug.; Cheboygan.

NETRIUM OBLONGUM (De Bary) Lütk. — Bog pools and shore of acid lake; May–Aug.; Cheboygan and Kalamazoo.

Var. CYLINDRICUM W. & G. S. West.* — Bog pools; July; Cheboygan.

ROYA ANGLICA West. — Bog pools; Aug.; Ingham.

SPIROTAENIA CONDENSATA Bréb.* — Bog pools; July–Aug.; Cheboygan.

SPIROTAENIA MINUTA Thur. — Bog pools; June; Cheboygan.

DESMIDIACEAE

ARTHRODESMUS BIFIDUS Bréb. var. TRUNCATUS West.* — Creek; June; Cheboygan.

ARTHRODESMUS CONVERGENS Ehrenb.* — Bog pools; July; Cheboygan; also Washtenaw (10).

ARTHRODESMUS INCUS (Bréb.) Hass.* — Bog pools and acid lake; July; Cheboygan.

Forma ISTHMOSA Heimerl.* — Bog pools; July; Cheboygan.

Forma MINOR West.* — Shallow pools and bogs; June–July; Cheboygan.

Var. INDENTATUS W. & G. S. West.* — Beach and bog pools; July; Cheboygan.

Var. RALFSII W. & G. S. West. — Bog pools; July; Cheboygan.

ARTHRODESMUS MICHIGANENSIS Johnson. — Washtenaw (4).

ARTHRODESMUS OCTOCORNIS Ehrenb.* — Beach and bog pools; July–Aug.; Cheboygan.

ARTHRODESMUS SUBULATUS Kütz.* — Bog pools and acid lake; July–Aug.; Cheboygan.

Var. SUBAEQUALIS W. & G. S. West.* — Bog pools; July; Cheboygan.

ARTHRODESMUS TRIANGULARIS Lagerh. forma TRIQUETRA W. & G. S. West. — Muskegon (9).

CLOSTERIUM ACEROSUM (Schrank) Ehrenb. — Lake, ditches, estuary along river, cold pools and bog pools; April–July; Chippewa, Branch, Hillsdale, Houghton, Jackson, Lenawee, Luce and Newaygo; also Van Buren (9) and Wayne (3).

Var. ANGOLENSE W. & G. S. West.* — Setback from slow creek and lake shores; Aug.; Cheboygan.

Var. ELONGATUM Bréb. — Setback along creek; May–Aug.; Cheboygan and Mecosta.

CLOSTERIUM ACUTUM (Lyngb.) Bréb. — Bog pools; Aug.; Cheboygan.

Var. LINEA (Perty) W. & G. S. West. — Bog pools; Aug.; Cheboygan.

CLOSTERIUM ANGUSTATUM Kütz.* — Bog pools; July–Aug.; Cheboygan; also Mackinac (9).

CLOSTERIUM ARCHERIANUM Cleve.* — Bog pools; Aug.; Cheboygan.

CLOSTERIUM ATTENUATUM Ehrenb. — Ditch; May; Newaygo.

CLOSTERIUM CORNU Ehrenb.* — Bog pools; July; Cheboygan.

CLOSTERIUM COSTATUM Corda.* — Bog pools; July; Cheboygan; also Wayne (3).

CLOSTERIUM CUSPIDATUM Bailey. — Muskegon (9).

CLOSTERIUM DECORUM Bréb.* — Bog pools, beach pools and lake shores; July–Aug.; Cheboygan, Houghton and Washtenaw; also Macomb (10).

CLOSTERIUM DIANAE Ehrenb. — Cold streams; June–July; Cheboygan and Delta; also Washtenaw (10) and Wayne (3).

CLOSTERIUM DIDYMOTOCUM Corda.* — Bog pools and lakes; July–Aug.; Cheboygan and Chippewa; also Muskegon (9).

CLOSTERIUM EBORACENSE Turner. — Bog pools and streams; July; Emmet; also Wayne (3).

CLOSTERIUM EHRENBERGII Menegh.* — Bog pools, creeks, ponds and ditches; April–Aug.; Cheboygan, Allegan, Genesee, Hillsdale, Houghton, Ingham, Ionia, Lenawee, Mackinac and Saginaw; also Allegan, Mackinac and Oakland (9).

Var. IMMANE Wolle. — Wayne (3).

CLOSTERIUM GRACILE Bréb.* — Bog pools; Aug.; Cheboygan.

Var. ELONGATUM W. & G. S. West. — Swamp pools; May; Mecosta.

CLOSTERIUM INCURVUM Bréb.* — Bog pools and setback from creek; July; Cheboygan.

CLOSTERIUM INTERMEDIUM Ralfs.* — Bog pools; July; Cheboygan; also Mackinac (9).

CLOSTERIUM JENNERI Ralfs.*—Bog pools; July–Aug.; Cheboygan.

CLOSTERIUM KUETZINGII Bréb. — Creeks, swamp pools and bogs; April–Aug.; Hillsdale, Houghton, Luce, Mackinac, Mecosta and Washtenaw; also Mackinac and Schoolcraft (9).

CLOSTERIUM LANCEOLATUM Kütz.* — Beach and bog pools, lake shores and estuary along lake; June–Aug.; Cheboygan, Emmet, Ionia, Newaygo and St. Clair.

CLOSTERIUM LEIBLEINII Kütz.* — Estuary along river, lake shores. streams and swamp pools; April–Aug.; Cheboygan, Allegan, Barry, Branch, Houghton, Lapeer, Saginaw and Sanilac; also Van Buren (9) and Wayne (3).

CLOSTERIUM LIBELLULA Focke.* — Polluted pool along shore of acid lake; Aug.; Cheboygan.

Var. INTERRUPTUM W. & G. S. West.* — Acid lake; Aug.; Cheboygan.

CLOSTERIUM LINEATUM Ehrenb.* — Beach and bog pools; July–Aug.; Cheboygan; also Allegan (9).

CLOSTERIUM LUNULA (Müll.) Nitzsch.* — Bog pools and setback along creek; July–Aug.; Cheboygan.

CLOSTERIUM MACILENTUM Bréb.* — Bog pools; July; Cheboygan; also Macomb (10).

CLOSTERIUM MALINVERNIANUM De Not.* — Setback along creek; July–Aug.; Cheboygan; also Macomb (4).

CLOSTERIUM MONILIFERUM (Bory) Ehrenb.* — Setback from creek, bog pools, cold streams, beach pools and acid lake; July–Aug.; Cheboygan, Emmet, Chippewa, Houghton and St. Clair; also Wayne (3).

CLOSTERIUM NAVICULA (Bréb.) Lütk.* — Acid lake and setback from cold creek; July–Aug.; Cheboygan.

Var. CRASSUM W. & G. S. West.* — Bog and small river; Aug.; Emmet and Cheboygan.

CLOSTERIUM PARVULUM Näg.* — Beach and bog pools, lake shores, ditches and setback from stream; March–Aug.; Cheboygan, Branch and Wayne.

Var. ANGUSTATUM W. & G. S. West.* — Beach pools; Aug.; Emmet.

CLOSTERIUM PERACEROSUM Gay. — Swamp pools; May; Barry.

Var. ELEGANS G. S. West. — Tamarack bog; May; Barry.

CLOSTERIUM PRITCHARDIANUM Arch.* — Marsh pools and setback from creek; May–July; Cheboygan and Jackson.

CLOSTERIUM PSEUDODIANAE Roy.* — Beach pools; Aug.; Emmet; also Oakland (9).

CLOSTERIUM ROSTRATUM Ehrenb.* — Bog pools, ponds and setbacks along slow streams; July–Aug.; Cheboygan; also Oakland (9) and Wayne (3).

CLOSTERIUM SILIQUA W. & G. S. West.* — Beach pools; Aug.; Emmet.

CLOSTERIUM STRIGOSUM Bréb. — Wayne (3).

CLOSTERIUM STRIOLATUM Ehrenb.* — Bog pools and ditches; May–Aug.; Cheboygan, Baraga and Mackinac; also Berrien and Mackinac (9).

CLOSTERIUM SUBTURGIDUM Nordst.* — Beach and bog pools; July; Cheboygan.

CLOSTERIUM TOXON West.* — Bog pools; July–Aug.; Cheboygan.

CLOSTERIUM TUMIDUM Johnson.* — Bog pools and ditches; May–July; Cheboygan, Ionia and Newaygo.

CLOSTERIUM VENUS Kütz.* — Bog pools; Aug.; Cheboygan; also Wayne (3).

COSMARIUM AMOENUM Bréb.* — Polluted beach pools, bogs and rarely lakes; July–Aug.; Cheboygan.

COSMARIUM ANGULARE Johnson. — Macomb (4).

COSMARIUM ANISOCHONDRUM Nordst. — Macomb (4).

COSMARIUM ANNULATUM (Näg.) De Bary.* — Bog pools; July; Cheboygan.

COSMARIUM BIOCULATUM Bréb. — Lake shores; June; Lapeer; also Wayne (3).

COSMARIUM BLYTTII Wille. — Marsh pools; May; Kalamazoo.

COSMARIUM BOECKII Wille.* — Shore of lake; July; Cheboygan.

COSMARIUM BOTRYTIS Menegh. — Bog pools and shore of lake; July–Aug.; Emmet; also Emmet and Cheboygan (9); Wayne (3).

Var. MEDIOLAEVE West.* — River; July; Cheboygan.

COSMARIUM BREBISSONII Menegh. — Pools in limestone quarry; July; Schoolcraft.

COSMARIUM CALCAREUM Wittr.* — Polluted beach pools and lake shores; Aug.; Cheboygan and Emmet; also Macomb (4).

COSMARIUM CAPENSE De Toni. — Washtenaw (10).

COSMARIUM CIRCULARE Reinsch. — Bog pools; July; Houghton.

COSMARIUM CONNATUM Bréb.* — Beach and bog pools; July; Cheboygan.

COSMARIUM CONSPERSUM Ralfs var. LATUM (Bréb.) W. & G. S. West.* — Shallow water of lake shore; Aug.; Emmet; also Macomb (10).

Var. ROTUNDATUM Wittr.* — Bog pools; July; Cheboygan.

COSMARIUM CONTRACTUM Kirchn.* — Beach and bog pools, rivers, bays; June–Aug.; Cheboygan, Emmet and Lapeer.

Var. ELLIPSOIDEUM (Elfv.) W. & G. S. West.* — Shallow water along lake shore; Aug.; Emmet.

COSMARIUM COSMETUM West.* — Shallow water along lake shore; Aug.; Emmet.

COSMARIUM CRENATUM Ralfs.* — Beach and bog pools; Aug.; Cheboygan and Emmet.

COSMARIUM CRUCIATUM Bréb. — Wayne (3).

COSMARIUM CUCURBITA Bréb.* — Beach and bog pools; July; Cheboygan.

Cosmarium cucurbitinum (Biss.) Lütk. forma minor W. & G. S. West. — Bog pools; July; Cheboygan.

Cosmarium cyclicum Lund. — Emmet (9) and Washtenaw (4).

Cosmarium cylindricum Ralfs.* — Beach pool; Aug.; Emmet.

Cosmarium dentatum Wolle. — Washtenaw (10) and Wayne (3).

Cosmarium docidioides Lütk.* — Bog pools and shallow water along creek; June–July; Cheboygan.

Cosmarium exiguum Arch. — Washtenaw (10).

Cosmarium formosulum Hoff.* — Beach pools, ditches and small streams; April–Aug.; Cheboygan, Emmet and Jackson.

Var. nathorstii (Boldt) W. & G. S. West. — Macomb (10).

Cosmarium globosum Bulnh. — Bog pools and acid lake; July; Cheboygan.

Var. wollei W. & G. S. West.* — Lakes, rarely in bogs; July–Aug.; Cheboygan.

Cosmarium granatum Bréb.* — Beach pools, lake shores and rivers; June–Aug.; Cheboygan, Emmet, Lapeer, Livingston and Mackinac.

Var. subgranatum Nordst. — Washtenaw (4).

Cosmarium hammeri Reinsch.* — Bog pools and acid lake; July–Aug.; Cheboygan.

Cosmarium holmiense Lund. var. integrum Lund. — Beach pool and lake shore; June–July; Cheboygan and Ionia.

Cosmarium impressulum Elfv.* — Beach pools and lake shores; June–Aug.; Cheboygan, Emmet and Lapeer; also Macomb (4).

Cosmarium inconspicuum W. & G. S. West. — Streams and marsh pools; July; Houghton and Schoolcraft.

Cosmarium intermedium Delp. — Slow river; July; Emmet; also Wayne (3).

Cosmarium kjellmani Wille.* — Polluted lake shore; Aug.; Cheboygan.

Cosmarium laeve Rabenh.* — Beach pool; Aug.; Emmet.

Cosmarium logiense Biss. — Lake shore; June; Lapeer.

Cosmarium lundellii Delp. var. ellipticum West. — Ditch; May; Ottawa.

Cosmarium maculatum Turner.* — Bog; July; Cheboygan.

COSMARIUM MARGARITATUM (Lund.) Roy & Biss.* — Bog pools and streams; July; Cheboygan.

COSMARIUM MARGARITIFERUM Menegh. — Wayne (3).

COSMARIUM MENEGHINII Bréb. — Lake shore; Aug.; Ingham.

COSMARIUM MODESTUM W. & G. S. West. — Washtenaw (10).

COSMARIUM MONILIFORME (Turp.) Ralfs. — Bog pools; Aug.; Cheboygan.

COSMARIUM MONOMAZUM Lund. var. TRISTICHUM W. & G. S. West. — Washtenaw (10).

COSMARIUM NITIDULUM De Not. — Wayne (3).

COSMARIUM NUDICEPS Johnson.* — Beach pool; July; Cheboygan; also Macomb (4).

COSMARIUM OBTUSATUM Schmidle. — Pool in gravel pit; June; Tuscola.

COSMARIUM OCHTHODES Nordst.* — Beach and bog pools; July–Aug.; Cheboygan.

COSMARIUM OVALE Ralfs.* — Bog pools; Aug.; Cheboygan.

COSMARIUM PACHYDERMUM Lund.* — Bog; July; Cheboygan; also Schoolcraft (9).

Var. AETHIOPICUM W & G. S. West.* — Bog and setback along river; July–Aug.; Cheboygan.

COSMARIUM POLYGONUM (Näg.) Arch. — Slow stream; July; Luce.

COSMARIUM PORTIANUM Arch.* — Lake shore, bog pools, rarely beach pools; June–July; Cheboygan; also Muskegon (9) and Wayne (3).

COSMARIUM PROTRACTUM (Näg.) De Bary.* — Rivers and beach pools; July; Cheboygan, Houghton and Washtenaw; also Wayne (3).

COSMARIUM PSEUDAMOENUM Wille.* — Bog pools; Aug.; Cheboygan.

COSMARIUM PSEUDOBROOMEI Wolle.* — Bog pools, ditches and lake shore; March–Aug.; Cheboygan and Wayne.

COSMARIUM PSEUDOPROTUBERANS Kirchn. — Macomb (4).

COSMARIUM PSEUDOPYRAMIDATUM Lund.* — Bog pools and slow stream; July–Aug.; Cheboygan and Emmet.

COSMARIUM PUNCTULATUM Bréb. — Cold streams and beach pools; June–Aug.; Emmet and St. Clair.

Var. SUBPUNCTULATUM (Nordst.) Börg.* — Beach pool; July; Cheboygan.

COSMARIUM PYGMAEUM Arch. — Macomb (10).

COSMARIUM PYRAMIDATUM Bréb.* — Bog pools and acid lake; July–Aug.; Cheboygan.

COSMARIUM QUADRATUM Ralfs.* — Bog pools; July; Cheboygan.

COSMARIUM QUASILLUS Lund. — Beach pools and lake shores; June–Aug.; Emmet and Wayne; also Washtenaw and Wayne (4).

COSMARIUM RADIOSUM Wolle. — Pools; July; Delta.

COSMARIUM RALFSII Bréb. — Wayne (3).

COSMARIUM RECTANGULARE Grun.* — Beach pool; July; Cheboygan.

COSMARIUM RENIFORME (Ralfs) Arch.* — Beach pools, lake shores and rivers; July–Aug.; Cheboygan and Livingston; also Macomb (10).

Var. ELEVATUM W. & G. S. West.* — Beach pool; Aug.; Emmet; also Washtenaw (10).

COSMARIUM RETUSIFORME (Wille) Gutw. — Macomb (10).

COSMARIUM SEXANGULARE Lund.* — Bog pools; July; Cheboygan.

COSMARIUM SPECIOSUM Lund.* — Bog pools; July; Cheboygan.

COSMARIUM SPINOSPORUM Lagerh. — Washtenaw (10).

COSMARIUM SUBARCTOUM (Lagerh.) Racib.* — Bog pools; July; Cheboygan.

COSMARIUM SUBCOSTATUM Nordst.* — Lake shores; Aug.; Emmet; also Emmet (9).

Forma MINOR W. & G. S. West.* — Beach pools; July; Cheboygan.

COSMARIUM SUBCRENATUM Hantzsch. — Marsh pools; July; Dickinson.

COSMARIUM SUBCUCUMIS Schmidle. — Streams; July; Emmet.

COSMARIUM SUBPROTUMIDUM Nordst.* — Bog pools and lake shore; July–Aug.; Cheboygan.

COSMARIUM SUBRENIFORME Nordst.* — River; July; Cheboygan.

COSMARIUM SUBSPECIOSUM Nordst. — Macomb (4).

Var. VALIDIUS Nordst. — Washtenaw (4).

COSMARIUM SUBTILE (W. & G. S. West) Lütk.* — Bog pools; July; Cheboygan.

COSMARIUM SUBTUMIDUM Nordst.* — Polluted lake shore, beach and bog pools and rivers; July; Cheboygan and Emmet.

COSMARIUM SULCATUM Nordst. — Macomb (4).

COSMARIUM SUPRASPECIOSUM Wolle. — Washtenaw (4).

COSMARIUM TAXICHONDRUM Lund.* — Bog pools; Aug.; Cheboygan; also Muskegon (9).

COSMARIUM TESSELLATUM (Delp.) Nordst. — Washtenaw (4).

COSMARIUM TETRAOPHTHALMUM Bréb.* — Shallow water along lake shore, beach pools and rivers; July–Aug.; Cheboygan and Emmet.

COSMARIUM TRACHYPLEURUM Lund. var. MINUS Racib.* — Bog pools; July; Cheboygan.

COSMARIUM TRIPLICATUM Wolle. — Washtenaw (4, 10).

COSMARIUM TUMIDUM Lund.* — Lake shore and bog pools; July–Aug.; Emmet.

COSMARIUM TURPINII Bréb. — Swamp pools and streams; May–July; Delta and Newaygo; also Gratiot (10).

COSMARIUM UNDULATUM Corda. — Small streams, ditches and lake shores; May–Aug.; Baraga, Chippewa, Ionia, Jackson, Lapeer, Livingston, Luce, Monroe and Muskegon.

Var. CRENULATUM (Näg.) Wittr. — Ditches and shallow water of lake shore; June–Aug.; Baraga, Cheboygan and Emmet.

Var. MINUTUM Wittr. — Bog pools, ditches and lake shores; July–Aug.; Cheboygan, Chippewa and Houghton.

Var. WOLLEI West. — Bog and swamp pools and ditches; June–July; Delta, Houghton and Ionia.

COSMARIUM UNGERIANUM (Näg.) De Bary var. SUBTRIPLICATUM W. & G. S. West.* — Bog pools; July; Cheboygan.

COSMARIUM VENUSTUM (Bréb.) Arch.* — Shallow water along lake shore; Aug.; Emmet.

COSMARIUM VEXATUM West. — Beach pools; Aug.; Emmet.

COSMOCLADIUM CONSTRICTUM Arch.* — Bog pools; July–Aug.; Cheboygan; also Schoolcraft (9).

COSMOCLADIUM PULCHELLUM Bréb. — Muskegon (9).

COSMOCLADIUM TUMIDUM Johnson. — Beach pools and lake shore; Aug.; Washtenaw; also Washtenaw (4).

DESMIDIUM AEQUALE W. & G. S. West.* — Lake shore, beach and bog pools; July–Aug.; Cheboygan.

DESMIDIUM APTOGONUM Bréb.* — Bogs, beach pools and creek; May–Aug.; Cheboygan, Kalamazoo and Kent; also Wayne (3)
Var. ACUTIUS Nordst. — Bog pools; Aug.; Ingham.

DESMIDIUM BAILEYI (Ralfs) Nordst.* — Bog pools; May–Aug.; Cheboygan and Kalamazoo; also Schoolcraft (9) and Wayne (3).

DESMIDIUM CYLINDRICUM Grev.* — Bog pools; July; Cheboygan; also Muskegon (9).

DESMIDIUM PSEUDOSTREPTONEMA W. & G. S. West. — Beach pool; July; Cheboygan.

DESMIDIUM QUADRATUM Nordst. — Bog pools and acid pond; July–Sept.; Cheboygan, Chippewa and Jackson.

DESMIDIUM SWARTZII Ag.* — Bog, marsh and swamp pools, ditches, beach pools and lake shores; May–Aug.; Cheboygan, Chippewa, Dickinson, Houghton, Ingham, Kalamazoo, Kent, Luce, Mackinac, Mecosta, Muskegon, Newaygo, Ontonagon, Ottawa and Schoolcraft; also Schoolcraft and Muskegon (9).
Var. AMBLYODON (Itzigs.) Rabenh. — Bog pools; May; Newaygo.
Var. SPINUOSUM Ackley. — Lake shore; May; Newaygo.

EUASTRUM AFFINE Ralfs.* — Pool in gravel pit and shore of acid lake; July–Aug.; Cheboygan and Chippewa.

EUASTRUM AMPULLACEUM Ralfs.* — Bog pools; Aug.; Cheboygan.

EUASTRUM ANSATUM Ralfs. — Muskegon (9).

EUASTRUM ATTENUATUM Wolle.* — Bog pools; July; Cheboygan.

EUASTRUM BIDENTATUM Näg.* — Beach and bog pools; July–Aug.; Cheboygan; also Schoolcraft (9).

EUASTRUM BINALE (Turp.) Ehrenb. forma GUTWINSKII Schmidle. — Pools and bog stream; Aug.; Ingham.

EUASTRUM CRASSUM (Bréb.) Kütz.* — Bog pools; June–Aug.; Cheboygan; also Emmet and Muskegon (9).

EUASTRUM DENTICULATUM (Kirchn.) Gay.* — Bogs; July–Aug.; Cheboygan; also Emmet and Muskegon (9).

EUASTRUM DIDELTA (Turp.) Ralfs.* — Pools in bog and gravel pit; July–Aug.; Cheboygan and Chippewa; also Emmet (9).

EUASTRUM DUBIUM Näg.* — Bog pools and slow stream; July–Aug.; Cheboygan and Emmet.

Var. SNOWDONIENSE (Turn.) W. & G. S. West.* — Small rivers and lake shores; July; Cheboygan.

EUASTRUM ELEGANS (Bréb.) Kütz. — Wayne (3).

EUASTRUM EVOLUTUM W. & G. S. West var. INTEGRIUS W. & G. S. West.* — Bog pools and lake shore; July–Aug.; Cheboygan.

EUASTRUM GEMMATUM Bréb. — Muskegon (9).

EUASTRUM HUMEROSUM Ralfs.* — Bog pools and acid lake; Aug.; Cheboygan.

EUASTRUM INSIGNE Hass.*.— Bog pools; July; Cheboygan.

EUASTRUM INSULARE (Wittr.) Roy.* — Bog pools; July–Aug.; Cheboygan; also Macomb (4).

EUASTRUM JENNERI Arch.* — Bog pools; July; Cheboygan.

EUASTRUM OBLONGUM (Grev.) Ralfs.* — Beach and bog pools; July; Cheboygan and Gogebic.

Var. CEPHALOPHORUM West. — Bog pools; July; Cheboygan.

EUASTRUM PECTINATUM Bréb.* — Beach pool; Aug.; Emmet.

EUASTRUM PINNATUM Ralfs.* — Bog pools; July–Aug.; Cheboygan; also Mackinac (9).

EUASTRUM ROSTRATUM Ralfs. — Ditch; July; Schoolcraft.

EUASTRUM SINUOSUM Lenorm.* — Bog pools and acid lake; July–Aug.; Cheboygan.

EUASTRUM TRIGIBBERUM W. & G. S. West.* — Bog pools; Aug.; Cheboygan.

EUASTRUM TURNERI West. — Creeks and lake shores; May–Aug.; Kalamazoo and Washtenaw.

EUASTRUM VERRUCOSUM Ehrenb.* — Small stream, ditch, beach pools and bog; May–July; Cheboygan and Chippewa; also Berrien (9) and Wayne (3).

Var. PLANCTONICUM W. & G. S. West. — Berrien (9).

Var. SUBLONGUM Ackley. — Bog pools; July; Chippewa.

GYMNOZYGA MONILIFORMIS Ehrenb.* — Beach and bog pools and lake shore; June–Aug.; Cheboygan, Emmet, Kalamazoo and Ontonagon; also Muskegon and Mackinac (9).

Var. GRACILESCENS Nordst. — Bog pools; July–Aug.; Cheboygan.

HYALOTHECA DISSILIENS (Sm.) Bréb.* — Beach, bog and swamp pools, gravel pits, ditches and slow streams; May–Aug.; Cheboygan, Barry, Calhoun, Chippewa, Houghton, Ingham, Kalamazoo, Luce, Mackinac and Ontonagon; also Allegan, Muskegon and Schoolcraft (9).

Var. HIANS Wolle. — Lake, bog and swamp pools, ditches and slow streams; May–Aug.; Cheboygan, Ingham, Mecosta and Saginaw.

HYALOTHECA MUCOSA (Mert.) Ehrenb.* — Bog pools and acid lake; July; Cheboygan.

Var. MINOR Roy & Biss.* — Beach pool; July; Cheboygan.

HYALOTHECA NEGLECTA Racib.* — Bog pools; July; Cheboygan.

MICRASTERIAS AMERICANA (Ehrenb.) Ralfs.* — Bog pools, cold springs, ditches and pools; May–July; Cheboygan, Delta and Houghton; also Berrien (9).

MICRASTERIAS APICULATA (Ehrenb.) Menegh. — Beach pools; July; Cheboygan; also Muskegon (9).

Var. FIMBRIATA (Ralfs) Nordst. — Wayne (3).

MICRASTERIAS CRENATA Bréb. — Bog pools; Aug.; Cheboygan.

MICRASTERIAS CRUX-MELITENSIS (Ehrenb.) Hass.* — Bog pools, rarely beach pools; July; Cheboygan; also Cheboygan (9).

MICRASTERIAS DENTICULATA Bréb.* — Bog pools, rarely gravel pits; July; Cheboygan and Chippewa.

Var. ANGULOSA (Hantzsch) W. & G. S. West.* — Bog pools; July; Cheboygan; also Muskegon (9).

MICRASTERIAS DEPAUPERATA Nordst. var. KITCHELII (Wolle) W. & G. S. West. — Bog pools; Aug.; Cheboygan.

MICRASTERIAS LATICEPS Nordst. — Wayne (3).

MICRASTERIAS MURRAYI W. & G. S. West. — Acid lake; July; Cheboygan.

MICRASTERIAS OSCITANS Ralfs. — Muskegon and Chippewa (9).

Var. MUCRONATA (Dixon) Wille. — Emmet (9).

MICRASTERIAS PAPILLIFERA Bréb. — Muskegon (9).

Var. GLABRA Nordst. — Lakes and bog pools; July; Cheboygan; also Muskegon (9).

MICRASTERIAS PINNATIFIDA (Kütz.) Ralfs.* — Beach and bog pools and lake; July; Cheboygan; also Muskegon (9).

MICRASTERIAS RADIATA Hass. — Muskegon (9) and Wayne (3).

MICRASTERIAS ROTATA (Grev.) Ralfs.* — Beach and bog pools, acid lake and gravel pit; July–Aug.; Cheboygan, Chippewa and Mackinac; also Cheboygan, Mackinac and Schoolcraft (9).

MICRASTERIAS SOL (Ehrenb.) Kütz.* — Bog pools and acid lake; May–July; Cheboygan and Kalamazoo; also Muskegon (9).

MICRASTERIAS TORREYI (Bailey) Ralfs. — Muskegon (9).

MICRASTERIAS TRUNCATA (Corda) Bréb.* — Beach and bog pools and acid lake; July–Aug.; Cheboygan; also Emmet, Mackinac and Schoolcraft (9), and Wayne (3).

ONYCHONEMA FILIFORME (Ehrenb.) Roy & Biss.* — Beach and bog pools and small lake; May-July; Cheboygan and Kalamazoo.

ONYCHONEMA LAEVE Nordst.* — Bog pools; Aug.; Cheboygan.

Var. MICRACANTHUM Nordst.* — Beach and bog pools; July–Aug.; Cheboygan; also Macomb (4).

PENIUM CYLINDRUS (Ehrenb.) Bréb.* — Bog pools and small streams; July; Cheboygan and Baraga.

PENIUM MARGARITACEUM (Ehrenb.) Bréb. — Slow streams; July; Luce; also Berrien (9).

PENIUM PHYMATOSPORUM Nordst.* — Bog pools; July; Cheboygan.

PENIUM SPIROSTRIOLATUM Barker.* — Bog pools; July–Aug.; Cheboygan; also Muskegon (9).

PLEUROTAENIUM CORONATUM (Bréb.) Rabenh. — Bog pools and lake shores; May–July; Cheboygan and Kalamazoo; also Muskegon (9).

PLEUROTAENIUM CRENULATUM (Ehrenb.) Rabenh. — Spring; Aug.; Cheboygan; also Wayne (3).

PLEUROTAENIUM EHRENBERGII (Bréb.) De Bary.* — Beach and bog pools; July–Aug.; Cheboygan; also Schoolcraft and Muskegon (9).

Var. ELONGATUM West. — Oakland (9).

PLEUROTAENIUM HUTCHINSONII (Turn.) W. &. G. S. West. — Bog pools; Aug.; Emmet.

PLEUROTAENIUM MAXIMUM (Reinsch) Lund.* — Beach, river and bog pools; July; Cheboygan.

PLEUROTAENIUM NODOSUM (Bailey) Lund. — Muskegon (9).

PLEUROTAENIUM TRABECULA (Ehrenb.) Näg.* — Bog pools, lakes, setbacks from streams, marshes and gravel pits; May–Aug.; Cheboygan, Emmet, Baraga, Chippewa, Delta, Houghton, Kalamazoo, Lapeer, Muskegon, Newaygo and Ontonagon; also Schoolcraft (9) and Wayne (3).

Forma CLAVATA (Kütz.) W. & G. S. West.* — Setback from creek, beach and bog pools; July–Aug.; Cheboygan and Houghton.

Var. RECTUM (Delp.) W. & G. S. West. — Lake shores; May–June; Muskegon; also Muskegon (9).

PLEUROTAENIUM TRIDENTULUM (Wolle) West. — Bog pools; July; Cheboygan.

PLEUROTAENIUM TRUNCATUM (Bréb.) Näg. — Muskegon (9).

SPHAEROZOSMA EXCAVATUM Ralfs.* — Bog; Aug.; Cheboygan; also Muskegon (9).

SPHAEROZOSMA GRANULATUM Roy & Biss.* — Bog pool; July; Cheboygan.

SPHAEROZOSMA VERTEBRATUM (Bréb.) Ralfs.* — Bog pools; July; Cheboygan.

Forma MINOR West. — Bog pools; July; Cheboygan.

Var. PUNCTULATUM W. & G. S. West. — Bog pools; July; Cheboygan.

SPHAEROZOSMA WALLICHII Jacobs. — Macomb (4).

SPONDYLOSIUM ELLIPTICUM W. & G. S. West. — Small lake; Aug.; Ingham.

SPONDYLOSIUM PAPILLOSUM W. & G. S. West.* — Bog pools; July–Aug.; Cheboygan; also Chippewa (9).

SPONDYLOSIUM PLANUM (Wolle) W. & G. S. West. — Stagnant pool; July; Ontonagon.

SPONDYLOSIUM PULCHELLUM Arch.* — Lake shore, beach pools and bogs; July–Aug.; Cheboygan; also Muskegon and Mackinac (9).

SPONDYLOSIUM PULCHRUM (Bailey) Arch. — Mackinac (9) and Muskegon (9).

SPONDYLOSIUM PYGMAEUM (Cooke) West. — Bog pools; Aug.; Cheboygan.

Var. MONILE (Turn.) W. & G. S. West.* — Bog pools; Aug.; Cheboygan.

STAURASTRUM ACULEATUM (Ehrenb.) Menegh.* — Bog pools; July; Cheboygan.

STAURASTRUM ALTERNANS Bréb.* — Beach and bog pools and ditches; July; Cheboygan and Houghton.

STAURASTRUM ANATINUM Cooke & Wills.* — Bog; July; Cheboygan.

Var. LONGIBRACHIATUM W. & G. S. West. — Lake shore; Aug.; Houghton.

STAURASTRUM APICULATUM Bréb.* — Beach and bog pools; July–Aug.; Cheboygan.

STAURASTRUM ARACHNE Ralfs.* — Bog pools; July–Aug.; Cheboygan.

STAURASTRUM ARCTISCON (Ehrenb.) Lund. — Muskegon (9).

STAURASTRUM ARISTIFERUM Ralfs.* — Bog pools; July; Cheboygan.

STAURASTRUM AVICULA Bréb.* — Beach and bog pools and slow streams; April and July; Cheboygan and Branch; also Wayne (3).

STAURASTRUM BICORNE Hauptfl.* — Shaded beach pool; July; Cheboygan.

STAURASTRUM BRACHIATUM Ralfs.* — Beach and bog pools; July; Cheboygan.

STAURASTRUM BRACHIOPROMINENS Börg.* — Bog pool; July; Cheboygan.

STAURASTRUM CERASTES Lund.* — Bog pools; Aug.; Cheboygan.

STAURASTRUM CONNATUM (Lund.) Roy & Biss.* — Bog pools; July; Cheboygan.

STAURASTRUM CUSPIDATUM Bréb.* — Beach pools and small creeks; July–Aug.; Cheboygan and Washtenaw.

Var. DIVERGENS Nordst.* — Lake shore and beach pools; July–Aug.; Cheboygan.

STAURASTRUM CYRTOCERUM Bréb. var. COMPACTUM W. & G. S. West. — Ditch; July; Houghton.

STAURASTRUM DEJECTUM Bréb.* — Bog pools; July–Aug.; Cheboygan.

STAURASTRUM DICKIEI Ralfs.* — Beach pool; July; Cheboygan.

STAURASTRUM DILATATUM Ehrenb.* — Beach and bog pools; July–Aug.; Cheboygan.

STAURASTRUM DISPAR Bréb. — Slow stream; July; Cheboygan.

STAURASTRUM ECHINATUM Bréb. — Bog pools; July; Cheboygan.

STAURASTRUM ELONGATUM Barker.* — Bog pools; July; Cheboygan.

STAURASTRUM ERASUM Bréb. forma ESPINULOSA W. & G. S. West. — Washtenaw (10).

STAURASTRUM FORFICULATUM Lund.* — Bog pools; July; Cheboygan.

STAURASTRUM FURCATUM (Ehrenb.) Bréb.* — Bog pools and small streams; June–July; Cheboygan and Chippewa.

STAURASTRUM FURCIGERUM Bréb.* — Beach pool and shallow ponds; July; Cheboygan, Delta and Manistique.

Forma ARMIGERA (Bréb.) Nordst.* — Bog pools; July; Cheboygan.

Var. EUSTEPHANA (Ehrenb.) Nordst.* — Beach pool; July; Cheboygan; also Wayne (3).

STAURASTRUM GLABRUM (Ehrenb.) Ralfs.* — Bog pools; July–Aug.; Cheboygan.

STAURASTRUM GLADIOSUM Turner.* — Bog pools; July–Aug.; Cheboygan.

STAURASTRUM GRACILE Ralfs.* — Beach and bog pools; May–July; Cheboygan and Kent; also Washtenaw (10) and Wayne (3).

Var. NANUM Wille.* — Lake shore, beach pools and bogs; July; Cheboygan.

STAURASTRUM GRANDE Bulnh.* — Bog pools; Aug.; Cheboygan.

STAURASTRUM HANTZSCHII Reinsch.* — Bog pools; July; Cheboygan.

STAURASTRUM HEXACERUM (Ehrenb.) Wittr. * — Bog pools; July; Cheboygan.

STAURASTRUM HYSTRIX Ralfs.* — Bog pools and acid lake; July–Aug.; Cheboygan.

STAURASTRUM INCISUM Wolle. — Washtenaw (4, 10).

STAURASTRUM INCONSPICUUM Nordst.* — Bog pools; July–Aug.; Cheboygan.

Staurastrum inflexum Bréb.* — Beach and bog pools; July; Cheboygan.

Staurastrum iotanum Wolle.* — Bog pool; July; Cheboygan.

Staurastrum irregulare West. — Washtenaw (10).

Staurastrum johnsonii W. & G. S. West. — Washtenaw (10).

Staurastrum laeve Ralfs. — Washtenaw (4).

Staurastrum leptacanthum Nordst. — Shallow lake; July; Livingston.

Staurastrum leptocladum Nordst. — Washtenaw (4).

Staurastrum manfeldtii Delp.* — Beach pool; July; Cheboygan.

Staurastrum margaritaceum (Ehrenb.) Menegh.* — Bog pools, ditches and lake shore; July–Aug.; Cheboygan, Ingham and Schoolcraft.

Staurastrum meriani Reinsch. — Stream and lake shore; May–June; Lapeer; also Berrien (9).

Staurastrum monticulosum Bréb. var. bifarium Nordst.* — Bog pools; July; Cheboygan.

Staurastrum muticum Bréb.* — Beach and bog pools; July–Aug.; Cheboygan and Ingham.

Staurastrum o'mearii Arch.* — Bog pool; July; Cheboygan.

Staurastrum orbiculare Ralfs var. depressum Roy & Biss.* — Beach and bog pools and limestone quarry; July; Cheboygan and Schoolcraft.

Var. hibernicum W. & G. S. West.* — Bog pools; July; Cheboygan.

Staurastrum pachyrhynchum Nordst.* — Bog pools; July; Cheboygan.

Staurastrum paradoxum Meyen. — Small lake; May; Muskegon.

Staurastrum polymorphum Bréb.* — Bog pools and acid lake; May–Aug.; Cheboygan and Kalamazoo; also Wayne (3).

Staurastrum polytrichum (Perty) Rabenh. — Beach and bog pools; July; Cheboygan and Houghton.

Staurastrum proboscidium (Bréb.) Arch.* — Beach pools; July; Cheboygan.

Staurastrum protractum (Wolle) Johnson. — Washtenaw (4).

Staurastrum pseudotetracerum (Nordst.) W. & G. S. West.* — Bog pools; July; Cheboygan.

Staurastrum punctulatum Bréb.* — Polluted pools, bogs, ditches and small streams; May–Aug.; Cheboygan, Emmet, Mecosta and Washtenaw; also Berrien (9), Washtenaw (10) and Wayne (3).

Staurastrum quadrispinatum Turner.* — Bog pools; July; Cheboygan.

Staurastrum ravenelii Wood. — Wayne (4) and Washtenaw (10).

Staurastrum saxonicum Bulnh.* — Beach and bog pools; July; Cheboygan.

Staurastrum sebaldi Reinsch.* — Bog and small lake; May–July; Cheboygan and Kalamazoo.

Staurastrum senticosum Delp.* — Beach pools; July–Aug.; Cheboygan and Emmet.

Staurastrum setigerum Cleve var. occidentale W. & G. S. West.* — Beach pool; July; Cheboygan.

Staurastrum simonyi Heimerl.* — Bog pools; July; Cheboygan.

Staurastrum spongiosum Bréb.* — Bog pools; July–Aug.; Cheboygan.

Var. griffithsianum (Näg.) Lagerh.* — Bog pools; July–Aug.; Cheboygan.

Staurastrum striolatum (Näg.) Arch.* — Bog pools; July; Cheboygan.

Staurastrum teliferum Ralfs.* — Beach and bog pools; July; Cheboygan.

Staurastrum tetracerum Ralfs.* — Bog pools; July–Aug.; Cheboygan.

Staurastrum trachytithophorum W. & G. S. West. — Bog pool; July; Chippewa.

Staurastrum trihedrale Wolle.* — Bog pool; Aug.; Cheboygan.

Staurastrum turgescens De Not. — Slow stream; April; Branch.

Staurastrum vestitum Ralfs.* — Beach and bog pools and lake shore; July–Aug.; Cheboygan.

Var. subanatinum W. & G. S. West.* — Bog pools; July; Cheboygan.

Var. tortum West.* — Bog pools; July; Cheboygan.

TETMEMORUS BREBISSONII (Menegh.) Ralfs var. MINOR De Bary.* — Bog pools; Aug.; Cheboygan.

TETMEMORUS LAEVIS (Kütz.) Ralfs.* — Bog pools and shore of acid lake; July–Aug.; Cheboygan.

TETMEMORUS MINUTUS De Bary.* — Bog; Aug.; Cheboygan.

TRIPLOCEROS GRACILE Bailey.* — Beach pool; Aug.; Emmet.

XANTHIDIUM ANTILOPAEUM (Bréb.) Kütz.* — Beach and bog pools and lake shore; July–Aug.; Cheboygan and Emmet; also Muskegon (9) and Wayne (3).

Forma JAVANICUM Nordst. — Washtenaw (4).

Var. MINNEAPOLIENSE Wolle. — Bog; July; Cheboygan.

XANTHIDIUM ARMATUM (Bréb.) Rabenh.* — Bog pools; July–Aug.; Cheboygan.

XANTHIDIUM BREBISSONII Ralfs. — Bog pools; July; Cheboygan.

XANTHIDIUM CRISTATUM Bréb.* — Beach and bog pools and ditches; July–Aug.; Cheboygan and Schoolcraft.

Var. LEIODERMUM (Roy & Biss.) Turner.* — Bog pool; Aug.; Cheboygan.

XANTHIDIUM FASCICULATUM Ehrenb. — Wayne (3).

XANTHIDIUM HASTIFERUM Turner var. JOHNSONII W. & G. S. West. — Washtenaw (10).

INDEX TO GENERA

PAGE
Arthrodesmus................ 121
Closterium.................. 122
Cosmarium.................. 125
Cosmocladium................ 129
Desmidium.................. 130
Euastrum................... 130
Gonatozygon................ 121
Gymnozyga.................. 131
Hyalotheca................. 132
Mesotaenium................ 121
Micrasterias................ 132
Netrium.................... 121

PAGE
Onychonema................. 133
Penium..................... 133
Pleurotaenium............... 133
Roya....................... 121
Sphaerozosma............... 134
Spirotaenia................. 121
Spondylosium................ 134
Staurastrum................. 135
Tetmemorus................. 139
Triploceros................. 139
Xanthidium................. 139

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DISTRIBUTION OF THE GENUS POTAMOGETON IN MICHIGAN

HENRY J. OOSTING

INTRODUCTION

THE genus Potamogeton forms one of the important elements of aquatic vegetation. No publication which concerns aquatics in general is complete without a discussion of the relationships of the genus with the other plants of aquatic habitat. All contributions to the vegetational conditions in marginal waters must recognize its importance because the genus constitutes a vegetational unit which makes up a large part of the inland aquatic vegetation.

The United States Department of Agriculture has done considerable investigation concerning its value as a game food. The starchy tubers and tuberous rootstocks are the favorite food of most ducks and the fruits and buds are eaten when available. The filiform types, such as *P. pectinatus,* are often eaten in their entirety. Methods of propagation and the conditions of growth are being studied so that the game preserves may be planted (12, 13, 14, 24).

In its relationship to animals the genus is as important as any aquatic group. Muskrats eat the plant tubers, and the larger fish feed on the tenderer forms. For every species of Potamogeton there are several species of insects whose larvae feed upon the plant, or at least pass a period of their lives upon it (2). These in turn may be related to the fish which feed upon them. Davis says that "plants furnish places of nesting, of refuge and of rest for fish, and a study of Walnut Lake records shows that the abundance of many fish and their permanence at any station was largely correlated with plant growth" (8). It is evident that the relationships of aquatic plants to animals will bear considerable investigation and that results may be of economic importance.

As marl-forming agents, the various species of Potamogeton probably stand next to the Characeae in importance. In the great peat deposits of the state of Michigan, borings invariably show the presence of some Potamogeton in the lakes of the past and in sufficient abundance to aid materially in the filling of the lakes and the building up of muck lands.

Considering the importance of the genus, it would seem that a survey of its distribution in a state so rich in conditions favoring its growth would be entirely justifiable.

To determine the distribution, the herbaria of Michigan State College, the University of Michigan and the Field Columbian Museum of Chicago were studied, as well as the private collections of Cecil Billington of Detroit, C. W. Fallass of Petoskey, and Professor B. A. Walpole of East Lansing. In addition, the writer made extensive collections in several counties in western Michigan. All available publications were consulted to increase the distribution records, but, because of the critical nature of the genus, only the reports which seemed most reliable and those of the commonest species were recorded.

Agnes Arber in her book on aquatic plants says: "The Pondweeds are an exceedingly difficult group from the point of view of the student of systematic botany, as the numerous species can, in many cases, only be discriminated as the result of much experience" (1). This difficulty of identification is due principally to the extreme variation of species, with the result that few specimens can be identified without careful investigation. Because of the critical nature of the genus, it has been divided into many subspecies and varieties. To consider these fine discriminations would require far more study than this survey involves.

The nomenclature as found in Britton and Brown's *Illustrated Flora of the Northern States and Canada*, second edition, has been used throughout this work. For identifying the more difficult forms it was necessary to supplement the Britton and Brown key with several others and of these the key of Gray's *New Manual of Botany*, seventh edition, and the key of Thomas Morong

(16), as found in his *Naiadaceae of North America*, were of most assistance. (Any further reference to Britton and Brown or to Gray's *Manual* applies to the editions named above.)

ENVIRONMENTAL RELATIONS

The aquatic habitat is so uniform and requires such definite characteristics for growth that the vegetation tends to be uniform in character. The submerged portions of all aquatics show tendencies toward simplification in both tissue structure and general form. The genus Potamogeton is no exception. Conducting tissues show no complexity, and other differentiation is reduced to a minimum. Most of the submerged leaves are but three cells in thickness. The two outer layers form the epidermis and the single layer between makes up the mesophyll. The epidermal cells are thin-walled, non-cutinized, and often contain more chlorophyll than do the mesophyll cells. This gives the leaves their characteristic deep green coloration. Further tendency toward simplicity can be seen in the form of the submerged leaves. All but a few are elongate, linear or ribbon-like and sessile on the stem. Species such as *P. americanus* and *P. amplifolius* have leaves which are somewhat elongated and taper to short petioles.

This simplicity and uniformity render identification difficult, but to make matters worse, in the genus Potamogeton the problem of variability in leaf form must also be contended with. Fruit characters are, however, constant and species may often be distinguished by good mature fruits only. The leaf venation, the type of stipule and manner of its attachment may usually be considered as invariable, and these aid materially in identification.

An illustration of the forms difficult to identify is the amphibious type of floating-leaved species. These are dwarfed, coarse forms, usually lacking submerged leaves and often without fruits. They develop when the water dries up or recedes to lower levels, leaving the aquatic plant to die or to adapt itself to the new conditions. Most water plants, unless highly specialized for aquatic life, are capable of producing such land forms when left in this condition. It is probable that the types having floating or aërial leaves are most successful because the least change is necessary for their establishment. In the genus Potamogeton the types with coriaceous, floating leaves are most commonly found in this condition. Fortunately, the leathery, floating leaves and the stipules retain their normal characteristics and they aid in identification. Occasionally fruits are produced, which simplifies matters somewhat, and comparison with forms in adjacent water may also aid. Forms which were collected while growing amphibiously or on land are *P. natans*, *P. americanus* and *P. heterophyllus*. In this condition these lack their submerged leaves. The floating leaves are shorter and heavier than in the water forms and some were collected which were partly buried in the mud.

Although the general form of a given species may be extremely variable, there are certain characteristics which are constant. The floating leaves are invariably coriaceous and unwettable, owing to a peculiar, waxlike coating not present on submerged parts. Unlike the leaves of terrestrial plants, these leaves cannot yield when battered by heavy rains, nor can they escape the constant motion of the water on which they float. As a consequence, these protective features are necessary to permit them to hold their positions successfully. In some submerged forms the entire plant is flexible and moves as a whole with the fluctuating water. This is truer of the filiform and ribbon types, which are often two or three times as long as the depth of the water in which they grow. *P. natans* has the stem axis fixed in the ground at an angle and by one end only. From this the petioles arise at an angle from pliable points of attachment which permit the leaf to respond to every water movement without resistance.

Light passing through water is reflected at the surface, absorbed by the water, and retained by substances in solution and suspension to such an extent that all submerged aquatics are of the "shade plant" type. They invariably have delicate leaves, little palisade tissue, and contain chlorophyll in the epidermis. It is possible that the filamentous, linear forms are produced to increase the leaf surface for combating the diminished light in water.

It is known that darkness will cause elongation in some terrestrial plants (17). The writer is of the opinion that this effect may be observed in some species of Potamogeton and that in some plants it may account for the variation in length of leaf. *P. epihydrus* collected in Pigeon Lake, Ottawa County, has excessively long, submerged leaves. Other species found here in the deeper water have noticeably elongated submerged leaves. The water coming in is slow-moving and drains from a boggy area which gives it a dark brown color. In Black Lake also the water has a dark color due to factory waste. Here the linear-leaved species, especially when growing in water of any depth with the resultant diminished light, tend to grow long and to float upon the surface, while the lower submerged part of the plant often reduces to the main stem only. *P. compressus* in particular was observed in this condition.

Another factor which may produce elongation in aquatic plants is strain due to current. This was brought to my attention again and again in the field. Whenever a species of Potamogeton was found growing in a swiftly moving stream, it was elongated far beyond the depth of the water in which it grew. Experiment has proved that a plant subjected to a steady pull in the direction of growth will eventually grow longer than one not so treated (17). It seems reasonable to conclude that the extreme elongation of these specimens was due, at least in part, to the pull exerted by the stream flow.

LIFE HABITS

The genus is so variable and adapts itself so easily to changing conditions that some species may be found in almost any body of water in Michigan. Stagnant or extremely filthy water, however, is not conducive to Potamogeton growth. Where the water is fresh and not too exposed or swift flowing, at depths varying from two decimeters to eight meters, some forms may almost invariably be found. Beyond this depth or in more open water it is almost impossible for the larger aquatics to establish or maintain themselves, with the result that the aquatic vegetation is somewhat concentrated along the margins of the water. Competition and the varying needs of the different types of vegetation have resulted in a definite arrangement of groups with relation to one another. These zones are almost invariable and are an outstanding characteristic of aquatic vegetation. But a comparatively few species can tolerate aquatic conditions and, since these conditions are quite uniform everywhere, aquatic floras are everywhere very similar. The few types adapted to aquatic life can endure certain conditions and no others, so that they are always found in definite habitats, always in the same zones, each zone dominated by a species or a group of species.

The attached marginal vegetation may ordinarily be divided into four general zones. Since conditions bearing on vegetation may vary, these zones must be modified for almost every lake when details are considered. First, along the shore in shallow water and to a depth of a meter is a zone characterized by sedges and rushes. Along the outer margin of this zone a few of the larger-leaved species of Potamogeton may be found, especially those with floating leaves. Of these, *P. natans* is a common form. The second zone is made up almost entirely of plants with floating leaves, such as Nymphaea, Nelumbo and Castalia. Because almost the entire water surface is covered with these large leaves, the submerged aquatics are forced to live outside the floating-leaved zone. In the deepest waters of the lake vegetation is extremely sparse and is limited almost entirely to species of Naias and Chara. Between this deep-water zone and the floating-leaved zone, we find the genus Potamogeton thriving as the dominant plant. Here almost any or all of the species may be found. When the water lilies or large floating-leaved types are absent, Potamogeton may occupy all the area from deep water to the sedges.

The width of the zones varies with the slope of the bottom. A steep narrow shelf with a sudden drop to deep water limits the width of the zones and the number of species which may take root there. Under such conditions the Potamogeton zone may not be present at all, or only a few scattered forms may be found along the margin of the drop-off. This condition is found in small deep lakes which are gradually disappearing. Then again, one part of a shore line may be in this steep condition whereas another in the same lake may have a wide shallow margin, gradually increasing in depth. The distribution of the genus here is obvious.

Associated with the genus Potamogeton are several other genera whose conditions for growth are practically the same. Elodea, Vallisneria and Myriophyllum species are common, while Brasenia is often found scattered through the two central zones. Their demands seem similar to those of the floating-leaved Potamogeton such as *P. natans*. Unattached species of Ceratophyllum and Utricularia are common also in almost any zone, and the small duckweeds such as Lemna and Wolffia may be found anywhere, although concentrated mostly in sheltered waters.

The genus Potamogeton is not limited to lake margins alone. In some shallow water bodies they may be scattered throughout. However, if these be lakes of any size and unsheltered, permitting rough water, then floating-leaved types in particular are rare, and the open water will have few if any species. *P. compressus*, which is heavily veined and has linear leaves and stem, combines strength with a minimum resistance to wave action. Specimens were collected in the center of Black Lake, Ottawa County, where they were exposed to the most extreme weather conditions. More fragile types, such as *P. pusillus*, probably would not survive in such locations, although having the same general form.

Collections of almost all species were also made in streams of widely varying character. The biological wealth of a stream varies inversely with its rate of flow, according to Pond (19). This statement is applicable to the genus Potamogeton, for whenever anything checks the flow of water, there conditions are more favorable for its development. Where the flow of the stream is checked, there is an accumulation of organic material and a deposition of rich alluvium, with the consequent increase of soil fertility and an increase in vegetation.

Some observations of habitat made in Black River, Ottawa

County, are of interest. Almost without exception the smaller filiform species were found in shallow water with sandy or gravelly bottom, whereas *P. americanus* was invariably found on clay bottom or next to a clay bank. Species with linear or ribbon-like leaves seem best able to survive in shallow and swift-moving streams. Several of these species were collected from shallow, swift-flowing, sandy-bottomed streams at scattered stations. The water often was little more than a decimeter in depth, but the plants were often a meter or more long and floating out on the surface.

The gelatinous or slimy sheath characteristic of so many water plants is conspicuously present in this genus. In some specimens it is only about the seeds and in others the young leaves and growing points may be encased in it. Again, the entire plant may have a thin coating. It has been suggested (19) that this covering may protect amphibious forms, and others too, from too rapid loss of water when exposed. Perhaps it is a protection for young buds and shoots against devouring animals. In submerged plants (1) the mucilage hinders the entry of water. Its true function has seemingly not been determined.

An incrustation is often found on the submerged leaves and stems of many of the Potamogeton species. This incrustation is a deposition of calcium carbonate. Several theories to account for its presence have been advanced (23). The commonest theory states that, when the plants withdraw carbon dioxide from the water for food manufacture, the soluble bicarbonate of lime, which is present in the water, is reduced to the insoluble neutral carbonate and deposited upon the plant surface:

$$CaH_2(CO_3)_2 \rightarrow CaCO_3 + CO_2 + H_2O$$

Another theory considers the oxygen liberated by the plant as a catalytic agent which acts on the bicarbonate to change it to a neutral carbonate. A more recent explanation rests upon the discovery that a soluble calcium salt of succinic acid is present in the cell sap of Chara. "The occurrence of this salt in the sap of other plants has not been determined, but as succinic acid is a very probable by-product in the ordinary processes of plant physiology, its wide distribution may reasonably be expected. As the calcium salt escapes from Chara by osmosis it is most likely decomposed with the formation of the insoluble carbonate" (19).

On some species of Potamogeton the incrustation is almost invariably present whereas on others it occurs only at times. On the ribbon-leaved species of Potamogeton and such aquatics as Vallisneria it seldom lodges, for their movements with the water probably set it free as soon as it is produced. In all cases the incrustation may easily be removed from the leaf. Its presence or absence does not seem to affect the life processes of the plant, since the most heavily incrusted specimens may be as large as those without a trace. So far as is known, the incrustation is a result of processes taking place within the plant and has no particular effect on the life processes of the plant which precipitates it.

The genus Potamogeton includes in its vegetative reproduction every possibility or means employed by other aquatics. Some species propagate by vegetative fragments. Some have rhizomes and tuberous rootstocks to carry them through the winter. Still others produce vegetative winter buds — hibernacula (3), propagules or turions, as they are variously called. These break off, drop to the bottom, and start new plants in the spring. Although vegetative reproduction is possible in so many ways, sexual reproduction is also well developed. Most of the species are wind-pollinated and in these the spikes will be found protruding just above the water. In *P. praelongus* the stem shortens after pollination and the spike is drawn under water, where the seeds mature. Several of the completely submerged species are pollinated under water. In these the pollen grains are filamentous structures that are as heavy as water, or heavier, and lack the thick exine characteristic of aërial pollen (6). Such pollen grains upon release float just beneath the surface and may come in contact with the long exserted stigmas.

Some members of the genus have almost completely ceased to produce seeds. *P. Robbinsii* Oakes is the rarest of North American species to fruit, with the exception of *P. interruptus* Kitaibel, which bears floral spikes quite freely, but which is not known to mature fruit in this country, though it does in Europe (10). Dr. Thomas Morong (16) writes as follows in regard to the fruiting of *P. Robbinsii:* "Very rarely, in years when the waters are low, the flowering spikes rise above the surface and perfect a few fruits. Dr. Robbins saw but one fruit, collected in Oregon by Hall. Mr. Faxon collected a few fruiting specimens in Jamaica Pond, Massachusetts, in 1880. Besides these, I have never known another instance, although the plant is very prolific in the localities where it occurs."

Of the specimens of *P. Robbinsii* I examined, none bore fruits. Specimens collected and observed in the field had spikes in various stages of maturity, and although a few appeared to have had fruits, none were collected or seen. *P. interruptus* was not collected, but of the specimens examined none bore even a trace of a spike. Emmeline Moore (15) says of *P. Robbinsii* that, in spite of the absence of fruits, propagation is readily effected. The branches, especially those with short internodes, become thickened and hardened through the storage of starch and, when detached, function as propagative structures. Since this enlargement and induration may take place at various points along the main axis, the final dismemberment of the whole plant provides enormous possibilities for the multiplication of the species.

P. pectinatus and *P. filiformis* are propagated by small tubers. These form at the ends of runner-like stems, which spread in all directions from the main axis of the growing plant. *P. perfoliatus* and *P. americanus* grow in beds or small groups. All are connected by a network of underground runners or roots. Miss Moore explains these as non-tuberous underground stems, rooting at the nodes and carrying the plant through the winter by the enlarged terminal portions which bear scaly buds. *P. heterophyllus* has its individuals connected in a series by an underground portion which is a series of short nodes and swollen internodes. Miss Moore calls this "propagation by tuberous rootstocks." This underground system of migration is very rapid in water plants, the soft mud of lake bottoms offering but little resistance to growth. Cowles (6) says that a meter advance in a year is not uncommon.

It is quite generally agreed that temperature variation in water is considerably less, taken the year around, than on land. In spite of this, there is always a possibility of freezing. To overcome this danger species which grow the year around, like *P. crispus,* sink to the bottom in winter. Others withstand the most extreme cold by means of their seeds or winter buds.

These winter buds are formed by the tips of branches with a closely packed, overlapping mass of leaves and stipules. These form in the late summer, and in the fall they separate from the parent. Owing to their compactness they are heavier than water and so sink to the bottom, where they rest through the winter. In the spring they resume growth like a simple vegetative branch.

P. compressus produces conspicuous winter buds and also plentiful fruits. *P. Friesii* and *P. pusillus,* which are smaller forms, also commonly produce both buds and fruits. Miss Arber (1) has shown that bud formation, in these types particularly, can be directly connected with unfavorable growth conditions. To substantiate this, I found that the smallest and weakest plants usually bore the most and the largest winter buds. These species, bearing both buds and fruits, have a general distribution and are very common forms. It is probable that this double method of reproduction helps to explain the distribution.

P. crispus forms a slightly different type of bud. Miss Moore (15) calls it a bur. Morong (16) groups both types together and speaks of them as propagating buds, whereas Miss Arber (1) calls them all turions. The bud of *P. crispus* is merely a much shortened branch with reduced leaves and a concentration of starch within it. The entire bundle hardens and this hardness, combined with the serrulate margins of the leaflets, gives the feeling and appearance of a bur. Large numbers of these buds are formed and, as nearly as I can learn, fruiting in *P. crispus* is quite uncommon. No fruits were found at the three stations where it was collected.

The advantage of carrying the plant through the winter by means of these buds is obvious. However, vegetative reproduction of this type has its disadvantages, chief of which is the limitation in rate of dispersal. The establishment of such species in distant habitats is almost impossible unless there are continuous waterways between, and the result is a slow migration.

DISTRIBUTION

Before one attempts to draw any conclusions from the records of distribution, several factors should be considered which influence these records and which will modify the interpretation somewhat.

Potamogeton species are often found in almost inaccessible places. Usually they are covered with a slimy sheath which makes them difficult to handle and requires special pains in preserving specimens. After being collected they decompose very quickly. Specimens in fruit are necessary for the identification of some species and fruiting specimens are often lacking. With these disadvantages it is obvious why collections of aquatic plants are limited.

Records for some species are very infrequent. Most of these bear close resemblance to more common species and can be distinguished only by careful study. The result is that the average collector does not recognize them in the field or after collection. In this class are *P. Oakesianus* Robbins, which is scarcely distinguishable from *P. natans* L., except in mature fruiting condition. Enough specimens of *P. Oakesianus* were examined and collected to enable me to feel certain that it grows in the state, and the wide separation of the points of collection would indicate that further search may reveal a general distribution. Several of the filiform species are even more difficult to recognize and identify.

Because of the variable character of the genus, the several species are capable of adapting themselves to almost any condition of habitat, with the result that most of the forms have a general distribution throughout the entire state. This is particularly true of the more prolific forms, such as *P. perfoliatus*, *P. heterophyllus*, *P. americanus* and the type species *P. natans*.

There is one exception to this general distribution. An area including Otsego, Montmorency, Kalkaska, Crawford, Wexford and Missaukee counties has no record of any specimens whatsoever. This would seem to indicate that conditions here are unfavorable to the growth of the genus. However, a study of detailed county maps of this area reveals that all have at least enough water to supply the conditions necessary for the growth of Potamogeton. Adjoining counties on all sides show general distribution for most species. The fact that the blank area is the same for every species leads to the conclusion that the area has probably not been sufficiently botanized.

Previous to the summer of 1926 the counties of Newaygo, Ottawa and Barry showed practically no records of Potamogeton collections. During that summer the writer botanized in these three counties with the result that practically all species found in the state were found there also. I conclude, therefore, that the total absence of records in some regions is due not to the absence of Potamogeton but to the absence of botanists.

Considering the species more in detail, we find several exceptions to the general conclusions. Several species have not been collected or reported in the state. Others are so rare that the authenticity of reports may be doubted, especially in species in which there is a close resemblance to some more common form. The greatest possible care was used in the identification of such forms. They were recorded only when the specimen had been thoroughly checked. Reports were not recorded at all in plants in the identification of which there was room for doubt.

Of *P. Faxoni* Morong but two reputed specimens were examined. The one from Genesee County, collected by D. Clark, agrees entirely with descriptions obtainable. However, the specimen of S. H. Camp, from Jackson County, is immature and also has many of the characteristics of *P. Americanus* C. & S. Gray's *Manual* holds that *P. Faxoni* Morong is an infertile hybrid of *P. alpinus* Balbis and *P. americanus* C. & S. If this is true — and neither of these specimens had mature fruits — then the poor distribution is somewhat explained. Its close resemblance to these other forms may also explain the lack of specimens on record for the state.

In Britton and Brown's *Illustrated Flora P. varians* Morong is spoken of as a hybrid of *P. angustifolius* Berch. & Presl. and *P. heterophyllus* Schreb., and it is limited to Mystic Pond, Medford, Massachusetts. Five good specimens were examined which were originally collected and identified by reliable botanists. They were collected in widely scattered stations in the state and the evidence would seem to indicate its establishment in Michigan. The records may be limited because of its close resemblance to *P. heterophyllus* Schreb.

P. crispus L. is a European species which has become established in the Atlantic coastal states and is gradually migrating inland. One specimen was examined which had been collected by Pennington in Van Buren County; during the summer I found *P. crispus* growing prolifically at three distinct stations in Ottawa County. The manuals limit the range of *P. crispus* to the eastern states. In 1913 E. D. Hull (11) wrote a short article on the advance of the species and showed it had but recently established itself in Illinois and Indiana, and that the points of establishment were along connected bodies of water. Because of its means of dispersal, previously mentioned, this seems entirely within reason. The bodies of water mentioned by Hull are connected with Lake Michigan and so migration to other neighboring bodies of water connected with it could well be expected. The collections made in Michigan were in the southwestern part, in small lakes connected with Lake Michigan, and it seems reasonably possible that the species could have migrated to these points from Illinois and Indiana, where it was already established in 1913. I have found no other record of its growth in the state, and in the several counties I worked I found no evidence of its presence. Tehon (20) discusses the present range of the species and attributes its westward migration to the agency of wild ducks.

Of the thirty-five species listed in the *Illustrated Flora* of Britton and Brown, seven have not been found in the state. *P. pulcher* Tuckerm. seems to be limited almost entirely to the Atlantic coastal states and the south. *P. mysticus* Morong, a depauperate form of *P. perfoliatus* L., is a local species found in a few stations in Massachusetts. *P. confervoides* Reichb., a delicate, filiform species, is restricted more to cold streams or mountain ponds (21) and is most common in the New England states, particularly Maine and New Hampshire. It is possible that further investigation may show its presence in the Upper Peninsula of Michigan. *P. gemmiparus* Morong is a local species found in the Atlantic states only. The range as given in Gray's *Manual* and the *Illustrated Flora* of Britton and Brown for *P. diversifolius* Raf. and *P. dimorphus* Raf. includes Michigan, but no specimens were collected or located for examination.

KEY TO THE SPECIES OF THE GENUS POTAMOGETON IN MICHIGAN

Treatment essentially as in Britton and Brown (4).

A. Plants with both floating and submerged leaves
B. Submerged leaves bladeless
a. Nutlets pitted, 4–6 mm. long, 3 mm. wide.. 1. *P. natans*
a. Nutlets not pitted, 3 mm. long, 2 mm. wide 2. *P. Oakesianus*
B. Submerged leaves with a proper blade
b. Submerged leaves capillary to linear
c. Submerged leaves capillary to linear-setaceous, 0.1–0.5 mm. wide, 1-nerved 22. *P. Vaseyi*
c. Submerged leaves linear, broader than above, several-nerved
d. Leaves ribbon-like, obtusely pointed; coarsely cellular-reticulated each side of midrib .... 4. *P. epihydrus*
d. Leaves broader at base, acute; no cellular-reticulation .... 8. *P. heterophyllus*
b. Submerged leaves linear-lanceolate to elliptic
e. Submerged leaves not of same type at upper and lower part of stem
f. Upper submerged leaves oval or elliptic, lower lanceolate, not pellucid; floating leaves 30–50-nerved; plant green .... 3. *P. amplifolius*
f. Upper submerged leaves petioled, lowest sessile; semipellucid; floating leaves 11–21-nerved; plant reddish tinged throughout .... 5. *P. alpinus*
e. Submerged leaves all of same type
g. Submerged leaves petioled
h. Floating leaves elliptic

i. Floating leaves broadly elliptic, rounded or subcordate at base .... 10. *P. illinoensis*
i. Floating leaves narrowly elliptic, tapering at base .... 6. *P. americanus*
h. Floating leaves obovate or oblanceolate, tapering at base ... 7. *P. Faxoni*
g. Submerged leaves sessile or subsessile
(a) Floating leaves pointed at apex, rounded or subcordate at base
(a) Floating leaves obovate or elliptic .... 8. *P. heterophyllus*
j. Fruit only 2 mm. long, obscurely 3-keeled .... 9. *P. varians*
j. Fruit 3 mm. long, distinctly 3-keeled .... 11. *P. angustifolius*

A. Plants with submerged leaves only
C. Stipules free from petioles
k. Leaf-blades rather broad, 6 mm. to 4 cm. wide, lanceolate or oblanceolate to ovate, several- to many-nerved
l. Leaves sessile or short-petioled, not clasping
m. Fruit distinctly 3-keeled, 2.5–4 mm. long; spikes 2.5–5 cm. long ...... 11. *P. angustifolius*
m. Fruit scarcely keeled, 3 mm. long; spikes 5–7.5 cm. long .... 12. *P. lucens*
l. Leaves clasping or half-clasping
n. Leaves half-clasping, elongate with rounded cucullate tips; stipules conspicuous; fruit sharply keeled . 13. *P. praelongus*
n. Leaves cordate-clasping; if elongate the plane of tips tapering; stipules inconspicuous or soon reduced to shreds; fruit rounded or scarcely keeled .... 14. *P. perfoliatus*
k. Leaf-blades narrower than 6 mm. (except in *P. crispus*), linear to oblong-linear; 1–7-nerved
o. Leaves glandless at base
p. Leaves linear, 3–5-nerved (except 16); 1–6 mm. wide.
q. Leaves delicate, 1–2 mm. wide, obscurely 3–5-nerved .... 18. *P. foliosus*
q. Leaves coarser, 2–6 mm. wide, two-ranked
r. Leaves 5-nerved, coarsely cellular-reticulate along midrib, ribbon-like .... 4. *P. epihydrus*

- r. Leaves with 3 principal and many fine nerves .... 16. *P. compressus*
- Leaves variable in shape, linear, oblong-linear, or linear-lanceolate, 3–7-nerved, 2–16 mm. wide
  - s. Leaves crisped, oblong-linear, serrulate, 3–7-nerved .... 15. *P. crispus*
  - s. Leaves not crisped, entire, pellucid, upper often petioled, lower sessile
    - t. Entire plant suffused with red; leaves obtuse, or rarely acute, narrowed at base; fruit 3-keeled, middle keel sharp .... 5. *P. alpinus*
    - t. Plant green, leaves acuminate or cuspidate; fruit indistinctly 3-keeled .... 8. *P. heterophyllus*
- o. Leaves with 2 glands at base
  - u. Leaves 3-nerved; spikes capitate
    - v. Leaves acute, cuspidate, 1–2.2 mm. wide; fruit 5 mm. long .. 17. *P. Hillii*
    - v. Leaves obtuse, mucronate, 1.5 mm. wide; fruit 2 mm. long .. 23. *P. pusillus*
  - u. Leaves 3–7-nerved, spikes not capitate
    - w. Leaves strict and revolute, 3–5-nerved, acuminate .... 21. *P. rutilus*
    - w. Leaves not as above, 3–7-nerved, obtuse, mucronate or cuspidate
      - x. Spikes ovoid, 6–9 mm. long; peduncles slender, erect ... 19. *P. obtusifolius*
      - x. Spikes interrupted, 7–12 mm. long, peduncles thicker than stem, sometimes thickening upward .... 20. *P. Friesii*

- C. Stipules adnate to leaves or petioles
  - y. Leaves very narrowly linear, less than 2 mm. wide, capillary to setaceous, 1-nerved or nerveless
    - z. Free part of stipule shorter than sheath; stigma broad and sessile
      - (a) Sheath of stipule less than 8 mm. long .... 24. *P. filiformis*
      - (a) Sheath of stipule more than 14 mm. long .... 25. *P. interior*
    - z. Free part of stipule equal to sheath; stigma capitate; style apparent ..... 26. *P. pectinatus*

y. Leaves linear, 2–6 mm. wide, nerves 3 to many
  (a) Leaves entire, 3–5-nerved .... 27. *P. interruptus*
  (a) Leaves minutely serrulate, finely many-nerved .... 28. *P. Robbinsii*

DISTRIBUTION

1. POTAMOGETON NATANS L.

Very common. Distribution general throughout. Ponds and slow-moving streams, depths varying from ½ to 2 meters. Often found in exposed water. This is the type species of the genus and is large and conspicuous. Submerged leaves reduced to phyllodes. Heavy, brownish tinged, floating leaves attached at right angles to petioles. Fruiting July, August.

Specimens examined: Berrien Co. (H. T. Darlington, 1917); Lenawee Co. (C. Billington, 1914); Monroe Co. (B. F. Chandler, 1913); Van Buren Co. (H. S. Pepoon, 1904); Kalamazoo Co. (E. B. Mains, 1913); Jackson Co. (S. H. and D. R. Camp, 1897); Washtenaw Co. (J. Dawson); Wayne Co. (C. Billington, 1915); Barry Co. (H. Oosting, 1926); Ingham Co. (C. F. Wheeler, 1900); Livingston Co. (F. L. Stearns, 1920); Oakland Co. (B. A. Walpole, 1919); Macomb Co. (D. Cooley, 1840); Ottawa Co. (H. Oosting, 1926); Montcalm Co. (C. F. Wheeler, 1900); Kent Co. (A. J. Pieters, 1897); St. Clair Co. (C. K. Dodge, 1904); Muskegon Co. (C. D. McLouth, 1899); Newaygo Co. (H. Oosting, 1926); Emmet Co. (C. W. Fallas, 1897); Iosco Co. (H. T. Darlington, 1918); Oscoda Co. (H. T. Darlington, 1918); Cheboygan Co. (F. C. Gates, 1911); Gogebic Co. (E. A. Bessey, 1920); Marquette Co. (A. Dachnowski, 1906).

Reported from Cass Co. (H. S. Pepoon, 1907); Calhoun Co. (C. E. Barr, 1908); Allegan Co. (F. A. Loew, 1913); Lapeer Co. (W. A. Brotherton, 1921); Tuscola Co. (C. K. Dodge, 1921); Huron Co. (C. A. Davis); Bay to Cheboygan Co. (occasional, C. K. Dodge, 1921); Chippewa Co. (C. K. Dodge, 1921); Schoolcraft Co. (C. K. Dodge, 1921).

2. POTAMOGETON OAKESIANUS Robbins

Infrequent. Distribution possibly general. Habitat same as that of *P. natans*, which it closely resembles except in size. Fruits desirable for identification. Fruiting July, August.

Specimens examined: Kalamazoo Co. (H. Oosting, 1926); Ingham Co. (H. Oosting, 1926); Clinton Co. (H. T. Darlington, 1918); Iosco Co. (H. T. Darlington, 1918); Gogebic Co. (H. T. Darlington).

3. POTAMOGETON AMPLIFOLIUS Tuckerm.

General throughout. Frequent. Mostly in lakes, at depths as great as 2½ meters. Often without floating leaves. Largest submerged leaves in the genus, usually incrusted with lime. Fruiting July, August.

Specimens examined: Berrien Co. (C. K. Dodge and H. T. Darlington, 1917); Lenawee Co. (H. Stocking); Kalamazoo Co. (E. B. Mains, 1913); Jackson Co. (S. H. Camp, 1897); Washtenaw Co. (F. L. Stearns, 1920); Wayne Co. (C. Billington, 1915); Ingham Co. (C. F. Wheeler, 1900); Ottawa Co. (H. Oosting, 1926); Kent Co. (C. W. Fallas, 1881); St. Clair Co. (C. K. Dodge, 1895); Montcalm Co. (C. F. Wheeler, 1900); Gratiot Co. (C. A. Davis, 1893); Newaygo Co. (H. Oosting, 1926); Oceana Co. (D. Cooley, 1850); Arenac Co. (?); Iosco Co. (C. F. Wheeler, 1898); Roscommon Co. (E. A. Bessey, 1925); Charlevoix Co. (C. F. Wheeler, 1894); Gogebic Co. (H. T. Darlington, 1919).

Reported from Calhoun Co. (C. E. Barr, 1908); Macomb Co. (E. J. Hill); Muskegon Co. (V. O. Graham, 1921); Huron Co. (C. A. Davis, 1907); Mason Co. (E. J. Hill); Cheboygan Co. (Gates and Ehlers); Schoolcraft Co. (C. K. Dodge, 1921); Marquette Co. (C. K. Dodge).

4. POTAMOGETON EPIHYDRUS Raf.

P. Claytonii Tuckerm.
P. pennsylvanicus Willd.
P. Nuttallii C. & S.

Frequent throughout. Lakes and streams. Commonly without floating leaves in running water. In swiftly flowing streams submerged leaves much elongated. In quiet water submerged leaves have characteristic fanlike arrangement. Fruiting July, August.

Specimens examined: Kalamazoo Co. (H. Oosting, 1926); Macomb Co. (D. Cooley, 1840); St. Clair Co. (Miss N. P. Whiting, 1894); Ottawa Co. (H. Oosting, 1926); Muskegon Co. (C. D. McLouth, 1899); Montcalm Co. (H. T. Darlington, 1919); Newaygo Co. (H. Oosting, 1926); Roscommon Co. (E. A. Bessey, 1916); Iosco Co. (H. T. Darlington, 1918); Alpena Co. (H. T. Darlington, 1918); Luce Co. (C. K. Dodge, 1915); Alger Co. (C. F. Wheeler, 1895); Marquette Co. (C. F. Wheeler, 1892); Gogebic Co. (H. T. Darlington, 1918); Keweenaw Co. (O. A. Farwell, 1888).

Reported from Oakland Co. (C. A. Davis, 1907); Tuscola Co. (C. K. Dodge, 1921); Chippewa Co. (C. K. Dodge, 1921); Schoolcraft Co. (C. K. Dodge, 1921).

5. POTAMOGETON ALPINUS Balbis

Infrequent. Distribution general. Entire plant suffused with reddish tinge. Fruiting July, August, September.

Specimens examined: Macomb Co. (A. J. Pieters, 1893); Kent Co. (C. W. Fallas, 1897); Charlevoix Co. (C. W. Fallas, 1918); Emmet Co. (J. H. Ehlers, 1922); Bois Blanc Island (S. H. Camp, 1894); Alger Co. (C. F. Wheeler, 1900); Marquette Co. (C. F. Wheeler, 1892); Gogebic Co. (E. A. Bessey, 1919); Keweenaw Co. (O. A. Farwell, 1888); Isle Royale (A. E. Foote, 1868).

Reported from Wayne Co. (O. A. Farwell, 1900); Cheboygan Co. (Gates and Ehlers).

6. POTAMOGETON AMERICANUS C. & S.

P. lonchites Tuckerm.

P. fluitans Roth.

Common. Distribution general. Slow streams and also lakes and ponds. Depths as great as 3 meters. Often without floating leaves and sometimes with floating leaves only, the large, delicate submerged leaves being broken up by movements of water. Calcium incrustation common. Fruiting July, August.

Specimens examined: Berrien Co. (H. T. Darlington, 1919); Cass Co. (H. S. Pepoon, 1904); Lenawee Co. (C. Billington, 1914); Monroe Co. (B. A. Walpole, 1920); Kalamazoo Co. (E. B. Mains, 1913); Calhoun Co. (W. J. Beal, 1898); Jackson Co. (S. H. and D. R. Camp, 1893); Washtenaw Co. (F. L. Stearns, 1920); Barry Co. (H. Oosting, 1926); Livingston Co. (F. L. Stearns, 1920); Macomb Co. (C. F. Wheeler, 1900); Ottawa Co. (H. Oosting, 1926); Shiawassee Co. (G. H. Hicks, 1890); Montcalm Co. (C. F. Wheeler, 1900); Newaygo Co. (H. Oosting, 1926); Huron Co. (C. A. Davis).

Reported from Wayne Co. (O. A. Farwell); St. Clair Co. (A. J. Pieters, 1894); Muskegon Co. (O. A. Graham, 1921); Bay to Cheboygan Co., frequent throughout (C. H. Dodge, 1921); Manistee Co. (F. P. Daniels); Keweenaw Co. (O. A. Farwell, 1904).

7. POTAMOGETON FAXONI Morong

According to Gray's *Manual*, seventh edition, infertile hybrid of *P. alpinus*. Previously discussed. Status doubtful.

Specimens examined: Jackson Co. (S. H. Camp, 1897); Genesee Co. (D. Clark).

8. POTAMOGETON HETEROPHYLLUS Schreb.

Distribution general. Very common. Extremely variable. Without floating leaves in rough water. Ordinarily the plants are found growing in a series connected by the rootstock. Fruiting July, August, September.

Specimens examined: Van Buren Co. (H. S. Pepoon, 1906); Kalamazoo Co. (H. Oosting, 1926); Jackson Co. (S. H. Camp, 1897); Washtenaw Co. (F. L. Stearns, 1920); Ingham Co., Livingston Co. (F. L. Stearns, 1920); Oakland Co. (C. Billington, 1916); Macomb Co. (A. J. Pieters, 1893); Ottawa Co. (H. Oosting, 1926); Kent Co. (1891); Clinton Co. (H. T. Darlington, 1918); St. Clair Co. (C. K. Dodge, 1904); Montcalm Co. (C.

F. Wheeler, 1900); Newaygo Co. (H. Oosting, 1926); Lake Co. (W. J. Beal, 1890); Huron Co. (C. A. Davis, 1896); Missaukee Co. (E. A. Bessey, 1916); Iosco Co. (C. F. Wheeler, 1888); Grand Travers Co. (1888); Alcona Co. (1888); Charlevoix Co. (C. F. Wheeler, 1892); Cheboygan Co. (F. C. Gates, 1911); Emmet Co. (C. W. Fallas, 1897); St. James Island (C. W. Wheeler, 1900); Alger Co. (C. Billington, 1916); Marquette Co. (A. Dachnowski, 1906); Gogebic Co. (H. T. Darlington, 1919); Ontonagon Co. (E. A. Bessey, 1923); Keweenaw Co. (O. A. Farwell, 1888); Isle Royale (A. E. Foote, 1868).

Reported from Cass Co. (H. S. Pepoon, 1907); Wayne Co. (O. A. Farwell, 1900); Tuscola Co. (C. K. Dodge, 1921); Muskegon Co. (V. O. Graham, 1921); Chippewa Co. (C. K. Dodge, 1921); Schoolcraft Co. (C. K. Dodge, 1921).

9. POTAMOGETON VARIANS Morong

Infrequent. Distribution probably general. Previously discussed. Closely resembles *P. heterophyllus* and has characteristics of several other species. Fruiting July, August.

Specimens examined: Macomb Co. (A. J. Pieters, 1893); Ottawa Co. (H. Oosting, 1926); Montcalm Co. (C. F. Wheeler, 1900); Cheboygan Co. (H. C. Beardslee, 1890); Mackinaw Co. (S. H. and D. R. Camp, 1924); Keweenaw Co. (O. A. Farwell, 1888).

10. POTAMOGETON ILLINOENSIS Morong

Two specimens collected and identified by McLouth and Walpole are doubtful. Both are immature and lack fruits. No other record or collections found in the state.

Specimens examined: Muskegon Co. (C. D. McLouth, 1894); Allegan Co. (B. A. Walpole, 1923).

11. POTAMOGETON ANGUSTIFOLIUS Berch. & Presl.

P. Zizii Roth.

Distribution general. No specimens or records from Upper Peninsula. Common. Very prolific in some areas. Fruiting July, August.

Specimens examined: Berrien Co. (H. T. Darlington, 1917); Kalamazoo Co. (H. Oosting, 1926); Washtenaw Co. (1838); Ingham Co. (Wheeler and Hicks, 1893); Livingston Co. (F. L. Stearns, 1920); Macomb Co. (A. J. Pieters, 1893); Clinton Co. (1884); Kent Co. (A. J. Pieters, 1897); Muskegon Co. (C. D. McLouth, 1890); Montcalm Co. (C. F. Wheeler, 1900); Huron Co. (C. K. Dodge, 1908); Iosco Co. (H. T. Darlington, 1918); Charlevoix Co. (C. F. Wheeler, 1892); Cheboygan Co. (C. F. Wheeler, 1890); Emmet Co. (J. H. Ehlers, 1921); Bois Blanc Island (1894).

Reported from Manistee Co. (E. J. Hill); Wayne Co. (D. H. Campbell); St. Clair Co. (A. J. Pieters, 1893).

12. POTAMOGETON LUCENS L.

Distribution general. Common in lakes and ponds. Usually may be distinguished by its large shining leaves. Fruiting July, August.

Specimens examined: Cass Co. (H. S. Pepoon, 1904); Van Buren Co. (L. H. Pennington, 1910); Kalamazoo Co. (H. Oosting, 1926); Washtenaw Co. (Miss G. Williamson, 1901); Ingham Co. (C. F. Wheeler, 1900); Livingston Co. (F. L. Stearns, 1900); Oakland Co. (B. A. Walpole, 1920); Macomb Co. (A. J. Pieters, 1893); Clinton Co. (H. T. Darlington, 1918); Kent Co. (A. J. Pieters, 1897); Ottawa Co. (H. Oosting, 1926); Newaygo Co. (H. Oosting, 1926); Iosco Co. (H. T. Darlington, 1918); Cheboygan Co. (F. C. Gates, 1911); Emmet Co. (C. W. Fallas, 1897); St. James Island (C. F. Wheler, 1900).

Reported from Wayne Co. (D. H. Campbell); Muskegon Co. (C. D. McLouth); Chippewa Co. (C. K. Dodge, 1921).

13. POTAMOGETON PRAELONGUS Wulf.

Distribution general. Common in deeper ponds and lakes, depths of 2 to 4 meters. Flowers at surface. Stem contracts, drawing fruits to deep water, where they mature. Large and coarse, can be recognized by the white stems and the large white stipules. Fruiting July, August.

Specimens examined: Cass Co. (H. S. Pepoon, 1906); Van Buren Co. (F. Gates, 1906); Kalamazoo Co. (E. B. Mains, 1913); Jackson Co. (S. H. Camp, 1897); Washtenaw Co. (F. L. Stearns, 1920); Ingham Co. (C. F. Wheeler, 1900); Clinton Co. (H. T. Darlington, 1900); Ottawa Co. (H. Oosting, 1926); Gratiot Co. (C. A. Davis, 1895); Montcalm Co. (C. F. Wheeler, 1900); Newaygo Co. (H. Oosting, 1926); Iosco Co. (H. T. Darlington, 1918); Cheboygan Co. (F. C. Gates, 1911); Gogebic Co. (H. T. Darlington, 1919); Ontonagon Co. (H. T. Darlington and E. A. Bessey, 1923).

Reported from Oakland Co. (C. A. Davis, 1907); Kent Co. (Emma J. Cole, 1901); Emmet Co. (Fallas and Swift, 1918).

14. POTAMOGETON PERFOLIATUS L.

P. Richardsonii Rydb.

Distribution general. Very common. In water as much as a meter in depth. Prolific. Leaves variable, orbicular to linear-lanceolate. May be distinguished from small specimens of *P. praelongus* by absence of white stipules and by the perfoliate base. Fruiting July, August.

Specimens examined: Berrien Co. (H. T. Darlington, 1917); Kalamazoo Co. (H. Oosting, 1926); Monroe Co. (B. F. Chandler, 1914); Washtenaw Co. (Miss H. W. Thompson, 1903); Wayne Co. (C. F. Wheeler, 1892); Barry Co. (H. Oosting, 1926); Ingham Co. (C. F. Wheeler, 1900); Oakland Co. (C. Billington, 1915); Macomb Co. (A. J. Pieters, 1893); St. Clair Co. (A. J. Pieters, 1893); Ottawa Co. (H. Oosting, 1926); Muskegon Co. (C. D. McLouth, 1894); Montcalm Co. (H. T. Darlington, 1917); Gratiot Co. (C. A. Davis, 1893); Newaygo Co. (H. Oosting, 1926); Huron Co. (C. K. Dodge, 1908); Iosco Co. (W. J. Beal and C. F. Wheeler, 1888); Antrim Co. (C. W. Fallas, 1920); Charlevoix Co. (H. D. Thompson, 1894); Cheboygan Co. (F. C. Gates, 1911); Emmet Co. (J. H. Ehlers, 1921); Alger Co. (C. F. Wheeler, 1900); Marquette Co. (A. Dachnowski, 1906); Gogebic Co. (H. T. Darlington, 1919); Isle Royale (A. E. Foote, 1861); Kent Co. (J. Shadduck, 1896).

Reported from Cass Co. (H. S. Pepoon, 1907); Van Buren

Co. (H. S. Pepoon, 1907); Bay Co. (G. M. Bradford); Schoolcraft Co. (C. K. Dodge, 1921).

15. POTAMOGETON CRISPUS L.

Three stations in Ottawa Co., one in Van Buren Co. A European species, established on the coast and migrating west along the watercourses. Leaves crisp, with margins crimped. Grows the year around. Not collected in fruit, but winter buds usually present.

Specimens examined: Van Buren Co. (L. H. Pennington, 1910); Ottawa Co. (H. Oosting, 1926).

16. POTAMOGETON COMPRESSUS L.

P. zosteraefolius Schum.

Very common. Distribution general throughout. Streams, ponds and lakes. In running or exposed water or in standing water. Collected at all depths, to 2 or 3 meters. Fruiting July, August.

Specimens examined: Berrien Co. (H. T. Darlington, 1917); Van Buren Co. (D. A. Pelton, 1880); Kalamazoo Co. (H. Oosting, 1926); Lenawee Co. (C. H. Stocking, 1861); Washtenaw Co. (W. H. Rush, 1891); Barry Co. (H. Oosting, 1926); Ingham Co. (C. F. Wheeler, 1892); Livingston Co. (F. L. Stearns, 1920); Oakland Co. (B. A. Walpole, 1919); Macomb Co. (A. J. Pieters, 1893); St. Clair Co. (C. K. Dodge, 1904); Ottawa Co. (H. Oosting, 1926); Kent Co. (A. J. Pieters, 1897); Clinton Co. (H. T. Darlington, 1918); Gratiot Co. (C. A. Davis, 1898); Montcalm Co. (C. F. Wheeler, 1900); Newaygo Co. (H. Oosting, 1926); Iosco Co. (W. J. Beal and C. F. Wheeler, 1888); Oscoda Co. (H. T. Darlington, 1918); Cheboygan Co. (F. C. Gates, 1911); Gogebic Co. (H. T. Darlington and E. A. Bessey, 1918).

Reported from Cass Co. (H. S. Pepoon, 1907); Wayne Co. (D. A. Farwell, 1900); Muskegon Co. (C. D. McLouth, 1896); Emmet Co. (Gates and Ehlers); Marquette Co. (C. K. Dodge, 1918).

17. POTAMOGETON HILLII Morong

Probably general, at least in the Southern Peninsula. Infrequent. Sometimes found without glands at leaf bases, but is easily recognized by the characteristic fruits. Fruiting July, August.

Specimens examined: Kalamazoo Co. (H. Oosting, 1926); Ottawa Co. (H. Oosting, 1926); Kent Co. (A. J. Pieters, 1897); St. Clair Co. (C. K. Dodge, 1896); Newaygo Co. (H. Oosting, 1926); Manistee Co. (D. A. Pelton, 1884).

18. POTAMOGETON FOLIOSUS Raf.

Occasional. Distribution general. In shallow water, lakes and streams. In fruit it can be identified at once by the irregular characteristic keel on the back. Fruiting July, August.

Specimens examined: Berrien Co. (C. K. Dodge and H. T. Darlington, 1917); Cass Co. (H. S. Pepoon, 1904); Van Buren Co. (L. H. Pennington, 1910); Kalamazoo Co. (S. E. Wolff, 1924); Washtenaw Co. (F. L. Stearns, 1920); Ingham Co. (H. T. Darlington, 1918); Ottawa Co. (H. Oosting, 1926); Ionia Co. (C. F. Wheeler, 1881); Genesee Co. (D. Clark); Montcalm Co. (C. F. Wheeler, 1900); Iosco Co. (W. J. Beal and C. F. Wheeler, 1888); Manistee Co. (E. J. Hill, 1880); Marquette Co. (A. Dachnowski, 1906); Keweenaw Co. (O. A. Farwell, 1886).

19. POTAMOGETON FRIESII Ruprecht

P. mucronatus Mann.

Distribution general. Frequent. Upper Peninsula distribution doubtful. Collected commonly in shallow, quiet water with mucky bottom. Fruiting July, August.

Specimens examined: Kalamazoo Co. (H. Oosting, 1926); Jackson Co. (C. F. Wheeler, 1898); Washtenaw Co. (C. H. Kauffman, 1923); Ingham Co. (C. F. Wheeler, 1900); St. Clair Co. (W. S. Cooper, 1901); Ottawa Co. (H. Oosting, 1926); Montcalm Co. (C. F. Wheeler, 1900); Newaygo Co. (H. Oosting, 1926); Mason Co. (C. E. Barr, 1909); Manistee Co. (E. J. Hill, 1880); Arenac Co. (C. F. Wheeler, 1900); Iosco Co. (W. J. Beal and C. F. Wheeler, 1888); Antrim Co. (C. W. Fallas, 1920); Emmet Co. (C. W. Fallas, 1921).

Reported from Wayne Co. (O. A. Farwell); Oscoda Co. (E. J. Hill); Cheboygan Co. (E. J. Hill).

20. POTAMOGETON OBTUSIFOLIUS Mert. & Koch

One station only, but specimen agrees perfectly with available descriptions. Fruiting August.

Specimen examined: St. Clair Co. (C. K. Dodge, 1904).

21. POTAMOGETON RUTILUS Wolfg.

Distribution general in south and probably throughout. Occasional. Propagating buds often absent. Fruiting July, August.

Specimens examined: Van Buren Co. (H. S. Pepoon, 1904); Jackson Co. (S. H. Camp, 1896); Monroe Co. (B. A. Walpole, 1920); Wayne Co. (C. F. Wheeler, 1892); Oakland Co. (B. F. Chandler, 1916); Kent Co. (W. E. Mulliken, 1896); Marquette Co. (A. Dachnowski, 1906).

22. POTAMOGETON VASEYI Robbins

One station only. Commonly grows without floating leaves and fruits rarely. August.

Specimen examined: St. Clair Co. (C. K. Dodge, 1896).

23. POTAMOGETON PUSILLUS L.

Very common. General throughout. Ponds and shallow, slow streams at depths from ½ to 2 meters. Variable in general form, but glands, buds and fruits invariable. This is one of the commonest species. Fruiting July, August.

Specimens examined: Cass Co. (H. S. Pepoon, 1904); Kalamazoo Co. (H. Oosting, 1926); Washtenaw Co. (W. H. Rush, 1891); Ingham Co. (C. F. Wheeler, 1892); Oakland Co. (B. A. Walpole, 1920); Macomb Co. (A. J. Pieters, 1892); St. Clair Co. (W. S. Cooper, 1903); Ottawa Co. (H. Oosting, 1926); Kent Co. (W. E. Mulliken, 1896); Newaygo Co. (H. Oosting, 1926); Iosco Co. (H. T. Darlington, 1918); Alpena Co. (C. F. Wheeler, 1895); Cheboygan Co. (J. H. Ehlers, 1921); Emmet

Co. (C. W. Fallas, 1918); Marquette Co. (C. K. Dodge, 1916); Gogebic Co. (H. T. Darlington, 1918).

Reported from Van Buren Co. (H. S. Pepoon, 1907); Wayne Co. (D. H. Campbell); Muskegon Co. (E. A. Bessey, 1920); Manistee Co. (E. J. Hill); Chippewa Co. (C. K. Dodge, 1921); Schoolcraft Co. (C. K. Dodge, 1921).

24. Potamogeton filiformis Pers.

Distribution general. Frequent. Shallow, quiet water. This is one of the most delicate species and can be recognized in the field by its filiform structure. Fruiting July, August.

Specimens examined: Kalamazoo Co. (E. B. Mains); Macomb Co. (A. J. Pieters, 1893); St. Clair Co. (C. K. Dodge, 1904); Ottawa Co. (H. Oosting, 1926); Montcalm Co. (C. F. Wheeler, 1900); Huron Co. (C. A. Davis, 1896); Iosco Co. (H. T. Darlington, 1918); Missaukee Co. (C. W. Fallas, 1897); Charlevoix Co. (H. S. Jennings, 1894); Cheboygan Co. (J. H. Ehlers, 1921); Chippewa Co. (D. A. Pelton, 1881); Gogebic Co. (H. T. Darlington, 1919).

Reported from Wayne Co. (O. A. Farwell); Emmet Co. (Gates and Ehlers).

25. Potamogeton interior Rydb.

Common. Distribution general. Shallow, warm water. Should be collected in fruit to distinguish it from *P. pectinatus*. Fruiting July, August, September.

Specimens examined: Kalamazoo Co. (H. Oosting, 1926); Jackson Co. (S. H. Camp, 1897); Barry Co. (H. Oosting, 1926); Macomb Co. (A. J. Pieters, 1893); Ottawa Co. (H. Oosting, 1926); Newaygo Co. (H. Oosting, 1926); Antrim Co. (C. W. Fallas, 1920); Charlevoix Co. (C. F. Wheeler, 1892); Emmet Co. (J. H. Ehlers, 1922); Gogebic Co. (H. T. Darlington, 1918).

26. Potamogeton pectinatus L.

Very common. General throughout. Shallow, warm water. Ponds and lakes. Is commonly a little smaller than *P. interior* and has the appearance of a fanlike comb in the water. Fruiting July, August, September.

Specimens examined: Berrien Co. (C. K. Dodge and H. T. Darlington, 1917); Cass Co. (H. S. Pepoon, 1904); Kalamazoo Co. (H. Oosting, 1926); Jackson Co. (S. H. and D. R. Camp); Lenawee Co. (D. Cooley, 1838); Washtenaw Co. (W. H. Rush, 1891); Wayne Co. (C. Billington, 1915); Macomb Co. (A. J. Pieters, 1893); Oakland Co. (C. Billington, 1915); Macomb Co., Livingston Co. (F. L. Stearns, 1920); Ingham Co. (C. F. Wheeler, 1892); Barry Co. (H. Oosting, 1926); Ottawa Co. (H. Oosting, 1926); Kent Co. (A. J. Pieters, 1897); Clinton Co. (H. T. Darlington, 1918); Genesee Co. (D. Clark); St. Clair Co. (C. K. Dodge, 1904); Muskegon Co. (C. D. McLouth, 1904); Newaygo Co. (H. Oosting, 1926); Midland Co. (R. R. Driesbach, 1918); Bay Co. (W. J. Beal and C. F. Wheeler, 1888); Roscommon Co. (H. T. Darlington, 1916); Manistee Co. (E. J. Hill, 1872); Cheboygan Co. (F. C. Gates, 1911).

27. POTAMOGETON INTERRUPTUS Kitaibel

Rare, but distribution general. Stations in the north, east and west. Rarely found in fruit.

Specimens examined: St. Clair Co. (C. K. Dodge, 1893); Cheboygan Co. (C. F. Wheeler, 1880); Manistee Co. (E. J. Hill).

28. POTAMOGETON ROBBINSII Oakes.

Four stations in the Southern Peninsula and one in the Upper Peninsula. Probably more general, but not recognized. If *P. epihydrus* is without floating leaves, the two are very similar in the water because of the opposite branching, which forms a fan. *P. epihydrus* has longer leaves and does not send a long fruiting stem up to the surface. It also lacks the serrate margins of the leaves.

Specimens examined: Washtenaw Co. (F. L. Stearns, 1920); Ingham Co. (C. F. Wheeler, 1891); Ottawa Co. (H. Oosting, 1926); Muskegon Co. (E. J. Hill, 1899); Marquette Co. (A. Dachnowski, 1906).

UNIVERSITY OF MINNESOTA

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SEED DEVELOPMENT IN *AMARANTHUS CAUDATUS* L.

EDWARD F. WOODCOCK

THE serum diagnostic investigations of Malligson (3) have shown that the families placed by Engler and Prantl (2) in the Caryophyllales or Centrospermae have a close relationship. The presence of a curved embryo, observed by Engler and Prantl and also by other investigators, is further proof of this close relationship. The true perisperm or endosperm nature of the storage tissue outside of the embryo in this order has been definitely determined by several recent investigators.

Artschwager (1) found the curved embryo and perisperm to be a characteristic of Chenapodiaceae. A small amount of endosperm was evident in the form of a cap over the radicle. The writer has found a somewhat similar condition in Aizoceae (13), Phytolaccaceae (7), Cynocrambaceae (12) and Caryophyllaceae (9, 10). Stevens (4) and the writer (5, 6) have shown that the storage tissue of Polygonaceae is endosperm and that the curved embryo prevails throughout the family. The writer has also shown that the embryo of Nyctaginaceae (11) is curved and centrally placed in an endosperm storage region and that the curved embryo of Portulacacea (8) has a sheath of vacuolated, somewhat crushed endosperm cells. In the latter family the storage region is perisperm. A brief summary of the foregoing observations is presented in Table I.

This paper deals with the seed morphology in *Amaranthus caudatus* L., a member of the Amaranthaceae and another representative of the Order Caryophyllales.

DESCRIPTION AND DISCUSSION OF THE MORPHOLOGY OF THE SEED

Microtome sections of seeds in various stages of development were used for study. The cell structure was made evident by the use of Delafield's hematoxylin.

TABLE I

SEED CHARACTERISTICS IN THE CARYOPHYLLALES

The shape of the embryo in each family is curved.

Family	Endosperm	Perisperm
Polygonaceae	Present	Absent
Chenopodiaceae	Present only as cap over tip of radicle	Present
Aizoaceae	do.	Present
Nyctaginaceae	Absent	Present
Phytolaccaceae	Present only as cap over tip of radicle	Present
Cynocrambaceae	Present	Absent
Caryophyllaceae	Present only as cap over tip of radicle	Present
Portulacaceae	Compressed sheath of empty cells about embryo	Present

The one-loculed ovary contains a single campylotropous ovule which is somewhat flattened, smooth and brownish black. The funiculus is very short (Pl. XIII, Fig. 1) and is only slightly evident in the later stages of seed development.

There are present two integuments, each composed of two layers of cells. The cells of the outer layer of the outer integument are radially elongated, whereas the cells of the inner layer are flattened. In the inner integument the inner layer of cells is thicker than the outer layer, and the integument becomes enlarged in the micropylar region (Figs. 2–3). The micropyle is formed in the inner integument only, since the latter projects beyond the outer integument. The embryo sac, at the time the proembryo is formed (Fig. 1), is slightly curved and extends about one third of the distance around the ovule to the chalazal region. It is separated from the integuments by a several-celled layer. In the micropylar region of this layer (Fig. 2) the cells are somewhat elongated and thus perhaps are better able to assist in the passage of the pollen tube from the micropyle to the embryo sac.

The proembryo very soon becomes differentiated into the embryo and many-celled suspensor (Fig. 2). By the time the meristematic regions of the embryo have become differentiated, the free nuclear endosperm forms a continuous layer about the wall of the embryo sac, the embryo and the suspensor. The sac has elongated and curved so that it extends to the chalazal region. A very interesting change has occurred in the integuments during this early stage of development. The outer layer of the inner integument has become much compressed and the inner tangential wall of the inner integument has become thickened and cutinized (Fig. 5).

As the embryo development proceeds, the free nuclear endosperm becomes cellular in the micropylar part of the sac and also along the sides (Fig. 4). The chalazal region remains in the free nuclear condition for a time. The sac is completely filled with cellular endosperm by the time the cotyledon and plumule primoidia begin to appear in the embryo. This endosperm is composed of large, thin-walled, vacuolated cells, which have no storage material in them. At this stage of development each of the cells of the nucellus has a few small, rounded starch grains (Fig. 6).

As growth proceeds, the developing embryo dissolves its way through the central part of the cellular endosperm (Pl. XIV, Fig. 7). At this stage of development the embryo consists of a cylindrical radicle and hypocotyl and two cotyledons which are semicircular in cross-section. At the base of the cotyledons is a rounded plumule. There is no indication of storage material in the endosperm at this time, but the cells of the nucellus are partly filled with small, rounded starch grains (Fig. 9).

The mature seed (Fig. 11) shows some very interesting structures. The testa includes three of the layers of the two integuments, the fourth layer having been almost completely obliterated (Fig. 10). The outer tangential wall of the outer integument is very thick and from its inner surface numerous projections extend into the cell cavity. Each cell of this outer layer of the outer integument is completely filled with dark staining cell contents. The inner surface of the inner tangential wall of the cells of the surviving inner integument has low, closely placed, uniform ridges projecting into the cell cavity. All of the cellular endosperm has been absorbed by the embryo except a cap of cells over the radicle. The cells of this cap are filled with storage material. The curved embryo lies in contact with the testa, and almost completely encircles the perisperm. Fully half of the embryo consists of cotyledons. The cells of the perisperm are densely packed with small starch grains (Fig. 8).

SUMMARY AND CONCLUSIONS

The ovule of *Amaranthus caudatus* L. is campylotropous, slightly flattened and nearly circular in outline. The curved embryo lies in contact with the testa and almost completely encircles the starchy perisperm. Some of the walls of the testa are thickened in a very characteristic manner to assist in the protection of the seed contents.

The similarity of the seed development of this representative of the family Amaranthaceae to other members of the Order Caryophyllales aids in establishing the close relationship of the families in this order, as pointed out by Malligson.

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12. —— 1929. Seed Development in *Thelygonium cynocrambe* L. *Ibid.*, 11: 341–346.

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EXPLANATION OF PLATES XIII–XIV

Seed of *Amaranthus caudatus* L.

All figures drawn with aid of camera lucida. The following abbreviations are used: C, cotyledons; CH, chalaza; E, embryo; EN, endosperm; ES, embryo sac; F, funiculus; H, hypocotyl; IN, inner integument; M, micropyle; N, nucellus; ON, outer integument; OW, testa; P, perisperm; PL, plumule; R, radicle; S, suspensor; ST, starch grains.

PLATE XIII

FIG. 1. Longitudinal section of young ovule, showing short funiculus, and embryo sac not fully developed. The dotted line in nucellus shows position which the embryo sac will occupy when mature (× 75)

FIG. 2. Detail of micropylar portion of ovule slightly older than that shown in Figure 1 (× 207).

FIG. 3. Detail of portion of outer and inner integument of young ovule (× 430).

FIG. 4. Longitudinal section of micropylar portion of ovule, showing extent of cellular endosperm (× 40)

FIG. 5. Similar to Figure 3, but showing a slightly older condition (× 207)

FIG. 6. Cell of nucellus with nucleus and a few starch grains (× 430)

PLATE XIV

FIG. 7. Longitudinal section of nearly mature ovule, showing the embryo sac completely filled with cellular endosperm and the embryo well developed (× 40)

FIG. 8. Cell of nucellus completely filled with small, rounded starch grains (× 430)

FIG. 9. Cell of nucellus partly filled with starch grains (× 430)

FIG. 10. Detail of portion of testa of mature seed (× 207)

FIG. 11. Longitudinal section of mature seed, showing testa, curved embryo with cap of endosperm, and perisperm (× 40)

PLATE XIII

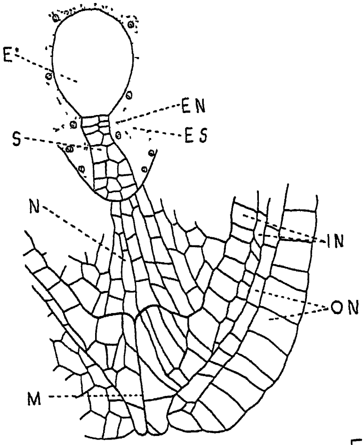

Fig. 2

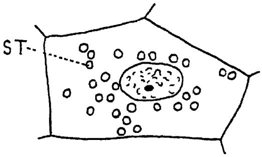

Fig. 6.

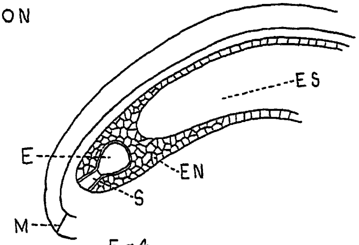

Fig. 4

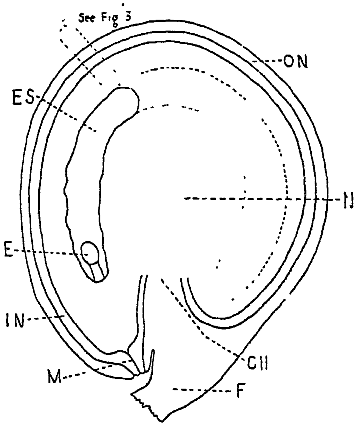

Fig. 1

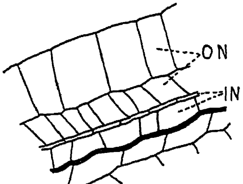

Fig. 5

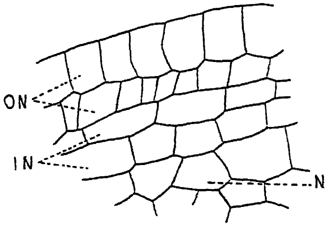

Fig 3

Seed of *Amaranthus caudatus* L.

PLATE XIV

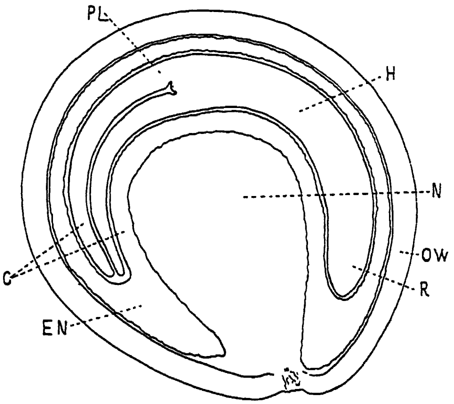

Fig. 7

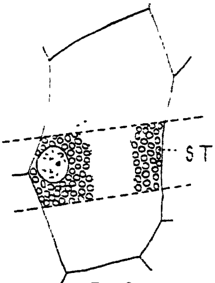

Fig. 9

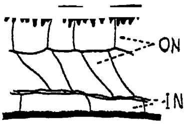

Fig. 10

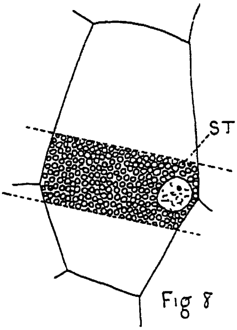

Fig 8

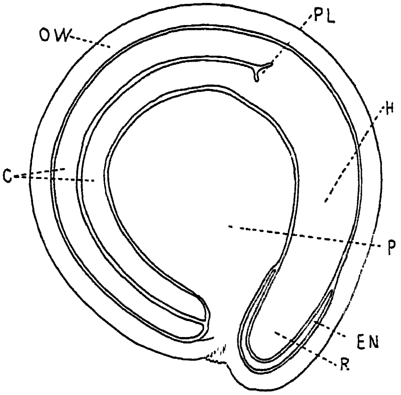

Fig. 11

Seed of *Amaranthus caudatus* L.

THE PENETRATING POWER OF THE RHIZOME OF QUACK GRASS, *AGROPYRON REPENS* (L.) BEAUV.

EDWARD F. WOODCOCK

THE presence of a rhizome of *Agropyron repens* (L.) Beauv. extending through a potato tuber is a common observation as the potato crop is harvested. So far as the writer has been able to learn, no careful study has ever been made to determine at just what age of the tuber the penetration occurs and also what tissue changes take place in the tuber and in the rhizome.

The penetration of a plant organ having much firmer tissues than that of the potato tuber has sometimes been observed, but no record made. Such a case was observed and called to the attention of the writer in the spring of 1930.

A one-year-old seedling of heart nut (*Juglans cordiformis* Maxim.) was found to have a quack-grass rhizome penetrating the root at a point about two inches below the ground line (Pl. XV, Fig. 2). At the time the seedling was removed from the ground the portion of the root through which the rhizome had passed was about one-half inch in diameter. The rather striking case of the herbaceous quack-grass rhizome going through a woody plant organ suggested to the writer the possibility that marked tissue changes might have occurred in the quack grass and in the root. A very detailed study was made of the external and internal changes. The portion of the grass within the Juglans root included the base of the internode and the node (Pl. XV, Fig. 1). The bark of the root surrounding the rhizome at the point of entrance and exit showed the same inrolling of the tissues which is evident in the bark of a stem as it heals over a wound. Several grass roots appeared to arise from the heart nut root, but in reality they had their origin from the imbedded node, as seen in Plate XV, Figure 1.

The study of the internal structure gave evidence that the root had been penetrated when the seed had just germinated and the seedling was still in the actively growing condition. The region of the root in contact with the rhizome showed no indication of the tearing which one would expect to find if the root had been penetrated after the woody tissues and pith had become well developed. The contact region of the root consisted of a several-layered periderm. The cells of this periderm which were in contact with the grass were larger and less regularly arranged than the underlying cells (Fig. 7). The periderm of this contact region was continuous with the periderm which had developed on the outside of the root as secondary thickening had occurred (Pl. XV, Fig. 1; Pl. XVI, Fig. 4). Since this periderm was continuous from the pith out through the woody ring, it would indicate that practically all of the woody tissue had been laid down after the grass had passed through the root. Another evidence of the development of the wood about the rhizome was seen in the wood cells directly opposite a lateral shoot which had attempted to develop from the imbedded node of the rhizome. These cells were smaller and thicker-walled than those in the parts of the root not in the vicinity of the rhizome (Pl. XVI, Figs. 5–6). This increase in thickness of wall was very probably due to the pressure of the retarded rhizome branch.

The rhizome itself was only slightly constricted in that portion within the root, thus indicating that no marked increase in diameter of the rhizome had occurred as secondary thickening of the root had taken place.

Longitudinal sections showed some very interesting details which made it quite clear just what had occurred. By studying tangential longitudinal sections of that part of the woody cylinder through which the rhizome had passed (Fig. 3), it was seen that all the woody ring had been laid down after the rhizome had passed through the root. The evidence appeared in the curved position of the mature tracheary and fibrous tissues and in the curvature of the vertical axis of each of the vascular rays. In this tangential section the periderm appeared corrugated, owing to its having grown into the depressions between the vascular bundles of the quack grass leaf sheath. In that portion of the pith through which the rhizome had passed, a space appeared above and below the rhizome, while at the sides the periderm was in contact with the rhizome (Fig. 2). The periderm about the rhizome in this region did not show the corrugations which were evident in the part that passed through the woody portion.

The structure of the Juglans root in that region about the rhizome shows that it was penetrated in that stage of development when the tissues were being laid down in the seedling and that during the development of the primary and secondary permanent tissues a periderm was formed next to the rhizome.

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EAST LANSING, MICHIGAN

EXPLANATION OF PLATES XV–XVI

Penetrating power of quack grass rhizome

Plate XV, photographs; Plate XVI, pen sketch and camera lucida drawings. The following abbreviations are used: B, bark; P, periderm; PI, pith; R, root; RH, rhizome; S, sclerenchyma; T, trachea; V, vascular ray; W, wood.

PLATE XV

FIG. 1. Cross-section of Juglans root showing the quack-grass rhizome imbedded in the root tissue. Periderm most evident in the pith region of the root

FIG. 2. Photograph showing the one-year-old Juglans seedling with rhizome passed through it

PLATE XVI

FIG. 1. Pen sketch showing inrolled bark of Juglans root and imbedded node of rhizome from which arise three roots

FIG. 2. Radial longitudinal section through pith of Juglans root showing the periderm and shape of cavity about the rhizome, the latter not shown in the drawing (× 16)

FIG. 3. Tangential longitudinal section through wood surrounding the imbedded rhizome, showing curved tracheae and vascular rays, and corrugated periderm (× 16)

FIG. 4. Somewhat diagrammatic drawing of portion of cross-section of root in vicinity of rhizome. Note the continuous periderm (× 16)

FIG. 5. Cross-section of xylem fibers in region marked "X" in Plate XV, Figure 1 (× 207)

FIG. 6. Cross-section of xylem fibers in region marked "Y" in Plate XV, Figure 1 (× 207)

FIG. 7. Cross-section of periderm (× 207)

PLATE XV

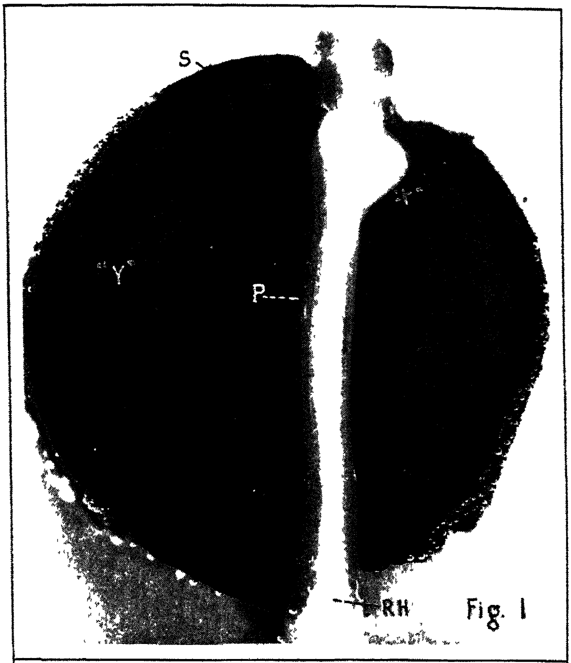

Fig. 1

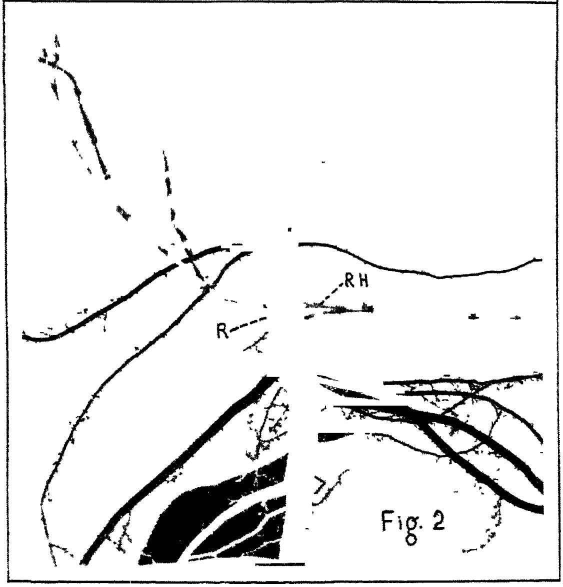

Fig. 2

PLATE XVI

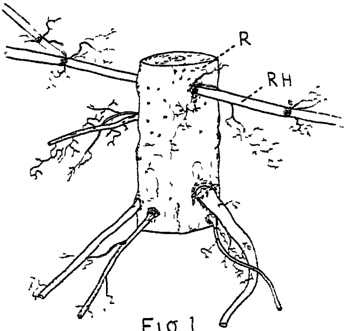

Fig 1

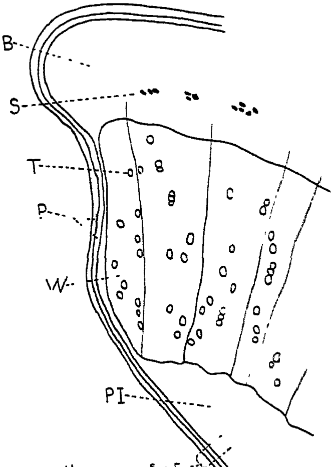

Fig 4

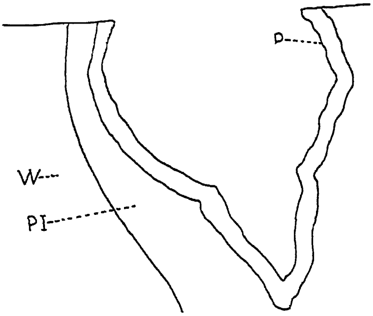

Fig 2

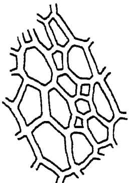

Fig 5

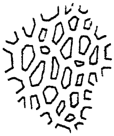

Fig 6

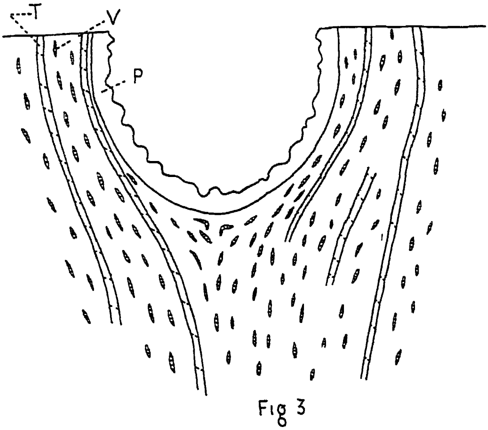

Fig 3

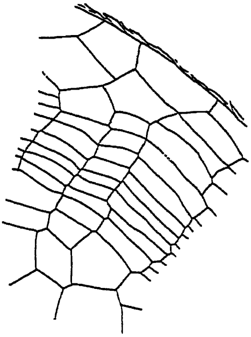

Fig 7

NOMENCLATURE IN THE LITERATURE OF FOREST FIRE CONTROL *

SHIRLEY W. ALLEN

THE title of this paper is more formidable than it was intended to be. Perhaps "terminology" would be a better word than "nomenclature." Certain misgivings, however, have been allayed through reference to an unsigned comment probably made by either Fernow or Zon in 1917: "The effort to put fire protection upon a more scientific basis is resulting in the development of a distinctive and technical nomenclature."[1] But regardless of what we name it, the language of forest fire prevention and control is of more than academic importance. We may admit that it is more essential to prevent and to extinguish fires than to write clearly about them. Confusion in the use of terms, on the other hand, means confusion in planning and execution. This defeats real accomplishment. It is always well to talk about what we are trying to talk about.

There exists a lack of agreement upon fire prevention and control terms used in the United States. A strip cleared in advance and designed to halt fire automatically or to serve as a safety zone from which to backfire is a "fire line," a "fire lane," a "firebreak," or even a "fire guard," depending upon the bailiwick of the writer. Again, a "fire line" is the edge of a burning area, a narrow trail scraped free of inflammable material at the edge or just outside the edge of a burning fire, or perhaps a natural feature such as a rock slide, a brook or a cliff. "Risk" and "hazard"[2] are frequently used synonymously and a recent inquiry

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* Contribution No. 23 from the School of Forestry and Conservation, University of Michigan.

[1] "Notes and Comments," *Journ. Forestry*, 15: 105. 1917.

[2] Sparhawk, W. N., "The Use of Liability Ratings in Planning Forest Fire Protection," *Journ. Agric. Res.*, 30: 694. 1925.

directed to three members of the Forest Service at three widely separated headquarters revealed three distinct ideas of the term "cold-trailing," which is used occasionally in forest fire literature.[3] Fires are "suppressed" on national forests and in numerous other localities, but in Pennsylvania they are "extinguished" — an eminently appropriate condition in which to leave them — and the costs of suppression there are "extinction costs."[4] Some of us practice "preparedness" in getting ready to attack and extinguish fires, taking our term directly from military parlance; others of us pass through a period of "presuppression." This term connotes time but no action. Still others pit "prevention and detection" against "extinction."[5] These are examples of the ambiguous terms most frequently encountered in literature on forest fires.

It will be profitable in the space allotted to consider a few terms which bid fair to persist and which carry more than one meaning, or fail to carry the thought which the writer or speaker has in mind.

Though much work has been accomplished in this direction, there is much left to be done and the wonder is that greater confusion does not exist in the language of this relatively new art. Difficulties are appreciated. They were so numerous at the time of the report of the Committee on Terminology of the Society of American Foresters in 1917 that the subcommittee charged with the work on protection terms decided to defer its portion of the report.[6] Fernow, as chairman of the main committee, evolved some guiding principles of terminology which are worthy of summarizing. In brief form they may be listed as follows: (*a*) The term should be necessary; (*b*) Words used for current well-established meanings should not be employed in another sense, particularly where ambiguity may result; (*c*) Age is a virtue and long usage and convenience should recommend retention, other things being equal; (*d*) Terms should be short and as nearly as possible self-explanatory; (*e*) A word or word combination should have a "term quality" (instinctive or intuitive rejection of the unsuitable).[7]

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[3] *Reforestation Act Amendments. Hearings before the Committee on Agriculture, House of Representatives, Sixty-eighth Congress,* Serial EE, p. 11. 1925.

[4] Wirt, Geo. H., "Major Forest Protection Problems," *Foresters' Conference,* Bull. 39, Commonwealth of Pennsylvania, Department of Forests and Waters, p. 70. 1929.

[5] *Ibid.*

[6] "Forest Terminology," *Journ. Forestry,* 15: 68. 1917.

The recently published glossary of the U. S. Forest Service,[8] which was first issued in mimeographed form in 1924, has cleared up much confusion, but it is essentially a Forest Service glossary in its present form, eschewing many terms which are synonymous with those included, or which are out of harmony with Forest Service practice. Its incompleteness and its failure to find satisfactory compromises are admitted,[9] but it is the most nearly complete list so far published. The Texas glossary is also worthy of mention.[10]

Let us now take up one by one a few terms for discussion.

"Control" is a stumblingblock of myriad meanings in all technical literature. Military science, plant pest work, business administration and forestry toss the word about continually and combine it endlessly with other words until one is inclined to agree with a western entomologist who doubts the existence of such a thing as "control."[11] Certainly the term wanders far afield in several directions from its narrow meaning of holding in check a force or an organism and preventing it from causing damage.

The term "fire control"[12] to cover all activities, including even prevention, is a convenient term as designated in the Forest Service glossary. We may forgive the coiner for attempting to control something which will not exist, should his prevention work attain perfection. It would be more nearly self-explanatory, however, if it read "fire prevention and control." One could then better understand another standard Forest Service term, namely, "control time," the definition of which reads: "Time from arrival of first man at fire until it is finally controlled. (Not to be confused with 'fire control' . . .)."[13]

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[7] *Ibid.*, p. 69.

[8] *Glossary of Terms Used in Fire Control, U. S. Dept. Agric., Misc. Publ. 70.* 1930.

[9] *Ibid.*, p. II.

[10] *Manual of Instruction for Texas Patrolmen. Bull. 19, Texas Forest Service,* Revised 1927, pp. 119–125.

[11] Woodworth, C. W., "There is No Control," *Science*, 70: 141. 1930.

[12] Page 8 of glossary cited in note 8.

Again, "hour control" means "*classification of area* according to the number of hours of time required for travel *to fires* from points at which employees and coöperators are stationed."[14] (The italics are mine.) But does it mean this? Not according to Show and Kotok, who say: "The speed-of-attack factor is usually termed 'hour control' and includes the total time elapsing from the start of the fire until the first suppression forces start work on the fire."[15] Not a word about classification of area. On the following page of this excellent bulletin one reads that ". . . the major controls of the rate of spread are (1) the cover type in which the fire occurs, (2) the character of the season during which it occurs, and (3) the exact conditions of wind and atmospheric humidity while it burns."[16]

Here, then, are five distinct usages of the word "control," to say nothing of the delightful abandon with which the word is used in conversation. Might it not be well to ask what we mean by "control"? Why not "suppression time" or "extinction time" for "control time"; "fire prevention and control" for "fire control"; "speed of attack" instead of "hour control"; and, finally, "factors affecting" rate of spread instead of "controls" of rate of spread? The right combination of two of the so-called "controls" in the latter case will put the rate of spread *out* of control. These proposed substitutions have more merit in the self-explanatory sense, in "term quality" and in dodging ambiguity, than they have in shortness or established usage. They seem worthy of study.

"Risk" and "hazard" have bothered foresters for many years in writing about fires. There is little comfort in the dictionaries and still less in the technical language of insurance. In everyday conversation they are frequently synonymous. The Forest Service glossary disposes of them arbitrarily and this scheme has much merit. "Risk" it defines as "the relative chance or probability of a fire starting, determined by the presence or absence of causative agencies. . . ." "Hazard," on the other hand, is "the relative amount, class, character, and condition of the fuels which constitute a part of the fire danger on any area. (Hazard concerns fuels only. Inflammability is the susceptibility of the fuels to ignition. Risk refers only to the agencies which cause fires. Danger is the sum of them all, plus damage and other factors.)" [17] This classification and definition are ingenious, but strictly arbitrary and certainly not self-explanatory or established by usage. For instance, Cook writes in 1921 (albeit he is thinking of "relative risk" as the insurance people call it): "This district has the smallest fire risk. This is undoubtedly due to three factors — small population, a moisture-retentive soil, and a good forest cover which has not been severely cut over. Of the three I give first importance to population. . . ." [18] Again, Coyle, as late as 1929, uses "risk" and "hazard" synonymously, although perhaps unconsciously so. He divides fire hazard into "passive," which includes fuels and conditions, and "active," which includes producer of the flame or spark (causative factors).[19]

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[13] Page 21 of glossary cited in note 8.

[14] *Ibid.*, p. 12.

[15] Show, S. B., and Kotok, E. I., *The Determination of Hour Control for Adequate Fire Protection in the Major Cover Types of the California Pine Region U. S. Dept. Agric. Tech. Bull. 209*, p. 2.

[16] *Ibid.*, p. 3.

For two years it has seemed advisable in my classes in fire prevention and control to connect the idea of hazard and risk (by whatever term seems most stable) with the broader concept of prevention. The problem of prevention is one of reducing or eliminating "hazard" and (or) "risk." I have told my classes that "human hazard," which includes the factors of thoughtlessness, carelessness, laziness and "cussedness," can be controlled only by public relations work, conveniences which make it easy for people to be careful, and law enforcement, including the closure practice in hazardous areas; that "physical hazard," on the other hand, includes presence and condition of fuel in places where any other hazard, human or natural, would ignite it. Hazard of the latter type is attacked by such means as clearing up camp sites and settings of logging donkeys and steam shovels, clearing inflammable growth or débris from the areas adjacent to travel routes of any kind, and disposing of slash. The real division of the factors of possible damage by fires is one of *people* and *fuels* or *sparks* and *tinder*. In effect, the Forest Service calls people "risk" and fuels "hazard," and it is within the Forest Service particularly that this concept begins to show use in literature. Is it best to accept the most widely used meanings regardless of their arbitrary selection? If so, then in area concerned and in volume of literature these specifications fit the Forest Service definitions.

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[17] Pages 12 and 19 of glossary cited in note 8.

[18] Cook, H. O., "Fire Risk in Massachusetts," *Journ. Forestry*, 19: 673. 1921.

[19] Coyle, L., "Basis for Determining Fire Protection Expenses," *Journ. Forestry*, 27: 148. 1929.

Suppose that we now come more closely home and consider the break-line-lane-guard-barrier muddle. Certainly there is nothing strange about the number or variety of terms used in this particular. There is both regional and traditional justification for them till the recent past. The situation reminds one that farm products are "hauled" in Iowa and "drawn" in New York State. Your coffee is "cooled" in Michigan and "colded" in Alabama. There is a "nigger in the woodpile" in California and a "bug under the chip" in Arkansas. We have "pep," "go-getterism," "elbow grease" and "git-up-and-git," depending upon places, work and workers. A lady is "carried" to a party in Mississippi and "taken" in Wisconsin. But why should a "firebreak" and a "fire line" not be separated without argument? Here in Michigan we speak of fire lines and call them "breaks" in the same paragraph.[20] A forester writer in a national forestry magazine mentions wide "firelines" built with a tractor and then observes that, "In reality this type of line is more of a firebreak than a fireline." [21]

Published definitions are interesting. In the Texas glossary the fire line is "the burning edge of a fire," and a firebreak is "a strip of space containing no combustible material."[22] In the Forest Service glossary a fire line is "The strip scraped or dug to mineral soil in a control line," and a firebreak is "a natural or constructed barrier made before a fire occurs. . . ."[23] In a Michigan report fire lines are "cleared roadways through the timber, brushed out to a width of about 20 feet and plowed and harrowed to a width of from 10 to 12 feet."[24] "Fire guard" is occasionally used, but in the Forest Service a "fire guard" is a man (not necessarily scraped, plowed or harrowed). Might not the Forest Service terms here be accepted to the advantage of all?

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[20] *The Department of Conservation, State of Michigan, Fifth Biennial Report, 1929–30*, p. 44.

[21] McIntyre, A. C., "Rapid Fireline Construction," *Am. Forests and Forest Life*, 34: 354. 1928.

As a constructive suggestion, might it not be well for us to have a committee to agree if possible upon terms used in fire prevention and control in Michigan? Such a group could be made up of two members from the Department of Conservation, and one each from the forest schools, the Michigan Academy, the Society of American Foresters and the U. S. Forest Service. This committee could establish state or regional usage and coöperate with the neighboring states and the Forest Service to "remove a barrier to an accurate exchange of thought."[25]

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[22] Page 121 of manual cited in note 10.

[23] Page 7 of glossary cited in note 8.

[24] *The Department of Conservation, State of Michigan, Fourth Biennial Report*, 1927–28, p. 26.

[25] Page II of glossary cited in note 8.

SOME RESUPINATE POLYPORES FROM THE REGION OF THE GREAT LAKES. III *

DOW V. BAXTER

IT HAS been recognized generally that the resupinate polypores are particularly difficult to identify. They are difficult not only because it is not always easy to separate them from pileate forms, but also because the characteristics of so many of these plants change upon drying. Furthermore, many herbarium plants upon which incomplete descriptions have been based are without spores. Many type collections are badly mixed, some are not to be found at all, and the descriptions of numerous species are inadequate. Because the descriptions are so scattered and poorly organized in the literature it is evident that a résumé to bring together the important characteristics of the porias of the region is badly needed. This paper presents in summary form the characteristics of diagnostic value used in the determination of the light-colored resupinate plants which have been collected in the region of the Great Lakes. A report on the brown porias of the region is reserved for a later publication.

The synopsis of the porias included in this paper is based primarily upon numerous collections which I have been making for more than ten years, and upon those made by the late Professor C. H. Kauffman and other investigators in the Lake States and elsewhere for a period of more than twenty years (2, 3). The measurements recorded for the plants, except the few noted, have been based largely upon the specimens obtained from this region. All available literature, however, has been used in making determinations, and the fresh specimens have been compared with herbarium plants and with original descriptions. The well-known

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and very excellent works of Dr. L. O. Overholts and other mycologists have been consulted freely, and many of their published findings are incorporated in this synopsis.[1] I have endeavored, however, to give due recognition for descriptive parts taken from the literature and for sections not based upon plants actually collected in the region.

In order to avoid some of the uncertainty which exists regarding the generic position of many plants commonly found in the resupinate state, I have included several such plants which belong to other genera in this synopsis. Some polypores are found in the resupinate form so often that they are commonly mistaken for porias and for this reason are included in the key presented in this paper. *Fomes annosus* Fr. may be cited as an example of a representative of another genus which is included here among the resupinates.

In an effort to obviate some of the difficulties encountered in making color distinctions, certain plants are placed in the key in more than one color group, although they are usually classified in .one section only by the majority of mycological students. Much confusion can be eliminated by a study of the colors of the growing plant, but it is not always possible to find the plant in this condition. Some plants differ so markedly in their color in herbarium specimens from that of fresh material that it is hoped that the arrangement of the specimens in more than one color section will be helpful in work of identification.

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[1] Throughout the work upon this report I am indebted to many individuals for help in identifications, for specimens and for suggestions. I am under special obligation to Dr. L. O. Overholts, who has given abundant and unstinted help. Acknowledgment is due to Dr. Lars Romell, Dr. James R. Weir and others who have identified specimens sent to them for study. I wish to express my appreciation to the authorities of the New York State Museum, the New York Botanical Garden, the Office of Pathological Collections in Washington, the Missouri Botanical Garden in St. Louis, the Field Museum of Natural History and the University of Wisconsin Herbarium. Thanks are also due to Miss E. M. Wakefield, curator of the Mycological Herbarium at the Kew Gardens, Kew, England, and to the authorities stationed at the herbarium at Uppsala and at the Riksmuseet Naturhistoriska in Stockholm. Appreciation is also expressed for the courtesies shown to me while visiting Dr. Ivar Jørstad, Statsmykolog, Oslo, Norway, and Dr. Torsten Lagerberg, Skogshogskolan, Experimentalfältet in Stockholm.

Throughout the later years of this study many herbarium specimens and types have been examined. The polyporaceous plants in the herbaria of the following institutions have been examined: the University of Michigan, the University of Wisconsin, the Field Museum of Natural History, the New York State Museum, the New York Botanical Garden, the Office of Pathological Collections in Washington and the Missouri Botanical Garden. I have also been privileged to examine types in the herbarium at the Kew Gardens, Kew, England, and to collect in the regions made known by such mycologists as Cooke, Smith and others. Opportunity has presented itself for procuring some specimens in Norway and Sweden, where special plants were studied not only in the field, but also in the herbaria at Uppsala and Stockholm.

The majority of the Friesian types are no longer in existence at Uppsala and are not to be found in the Riksmuseet, but in their absence Romell's interpretation of the Friesian and especially of the northern European plants has been followed as closely as is practicable. I have had an opportunity to study many of Romell's collections, not only those in Stockholm but also specimens which were sent to me by this eminent scholar some years ago. Many of the plants which appear in the key have been based upon American specimens sent to Romell for study. Although Bresadola's collection is to be found at the Riksmuseet, the plants in this herbarium show that his interpretation of many of them differs greatly from that of Romell, so that I am inclined not to confuse Bresadola's ideas with those of Romell in this paper. Many reported synonyms, however, are included in the key for convenience.

The porias from the region of the Great Lakes are, in general, similar to those which are found in the northeastern section of the United States, in the southern Appalachian forests, and in the central hardwood region. The numerous hosts and substrata which are to be found in the region of the Great Lakes partly explain the fact of this general occurrence. Our forests are represented by a variety of types found in New England, in the southern Appalachians, and in the central hardwood districts. The spruce-fir forests are found in the swamps of Michigan, Wisconsin and Minnesota; the mixed forest region of white, red and jack pine occupy extensive areas in these states; and the northern hardwood types composed of birch, beech and maple — trees found in the southern Appalachian Mountains — are common to the northern sections. The porias found throughout the oak, oak-hickory and other types of the hardwood region are to be found in southern Michigan and Wisconsin, and many of them occur in Minnesota also.

Although southern porias are not well known, many of those found in the South are common to this region. Some porias, however, such as *P. borbonica* Pat., seem to be distinctly southern in their distribution. Many of the resupinate polypores which have been collected in the western coniferous forests have not been found on the conifers indigenous to the region of the Great Lakes. My herbarium contains many western porias which seem to be entirely foreign to Michigan, Wisconsin and Minnesota. Such cosmopolitan plants as *P. subacida* (Pk.) Sacc., *P. ferruginosa* (Schrad.) Fr., *P. medulla panis* (Pers.) Cooke, *P. attenuata* (Pk.) Cooke and a few others may commonly be found, however, in both the West and the East. Several other western species are closely allied to *P. subacida* and *P. medulla panis*, and there seem to be many more which could logically be placed under the genus Trametes.

The majority of the resupinate polypores in the region of the Great Lakes do not occur frequently enough to be considered of much economic importance and do not play a significant rôle in the decay of timber. *P. incrassata* (Berk. & Curt.) Burt which produces a dry rot in buildings and stored construction materials in the South (9) and on the Pacific Coast, is not represented in the Michigan and Wisconsin collections. Another poria, *P. vaporaria* Fr., which is reported as the cause of serious damage to beams and other structural timbers elsewhere, has not been extensively collected in the region, and no reports of its causing a loss in building timbers in Michigan are known. *P. vaporaria* (as interpreted by Burt, Pl. XVII) rots the bark and the wood of the roots of injured or dead citrus trees in California

(8), but there are no known infections of this fungus on any trees which grow in Michigan and Wisconsin or near the Great Lakes.

There are comparatively few porias which might be considered important from the standpoint of decay of slash. In hardwood slash, which is found in the woodlots in the southern sections of this region, *P. medulla panis* and *P. ferruginosa* are the only species which might be classified as common plants. During the course of a detailed five-year study of the fungi which occur in hardwood slash near Ann Arbor, no porias have been found. For northern Michigan, records have been compiled which summarize the list of fungi which have been collected on the lopped branches in the northern swamp timber types. Although studies have been made at different seasons on this slash felled in 1917, 1918, 1922, 1924, 1926, 1927, 1928 and 1929, only nine species of Poria have been found. These plants, *P. subacida, P. ferruginosa, P. xantha* var. *calcea* (Lind.) Romell, *P. subincarnata* (Pk.) Murr., *P. papyracea* (Schw.) Cooke, *P. sinuosa* Fr., *P. lenis* Karst., *P. vulgaris,* and an unidentified species which is very similar to *P. flavicans* Karst., are all common in northern Michigan timberlands. Of these species *P. subacida* plays the most important rôle in the decay of such northern timbers. This fungus is associated with the so-called "feather rot" in *Abies balsamea* Mill. and is apparently an important contributory to wind throw in affected balsam (10). Such windfall is prevalent in almost all stands where balsam occurs in the northern sections of the Lake States. In the region of the Great Lakes white pine, birch, tamarack, balsam, spruce, hemlock, black ash and jack pine are recognized substrata for *P. subacida.* This plant is known, however, from almost all sections of the country and on a great variety of genera, such as Thuja, Quercus, Liquidambar, Juglans and Castanea.

KEY TO THE PORIAS FROM THE REGION OF THE GREAT LAKES

(The section on brown porias will appear in a later publication.)

1. Fruiting-body white, whitish or cream-colored (buff), at least when fresh 2
1. Fruiting-body of some other color 44

WHITE PLANTS

2. Pore mouths 1–3 to a mm. or plants having 3–4, but not more than 4, and usually 3 or fewer than 3 3
2. Pore mouths 4 or more to a mm. or plants having 2–5, but mostly 4 or more 29

3. Context corky, not usually distinct from the tubes; tubes not in a distinct layer, trametes-like, arid; spores subglobose, oblong ellipsoid-cylindric.. 4
3. Context not corky or trametes-like; subiculum more or less distinct from the tubes, plant not arid 8

4. Spores mostly 4.5–5 μ long, and not longer than 5.5 μ 5
4. Spores at least 6 μ long 6

5. Spores 4.5 × 5 μ; tubes 2–6 mm. long; mouths white or slightly yellowish. Cystidia not present. Pileus, when present, brown or light brown on upper surface. On conifers .... *Fomes annosus* Fr.
5. Spores 4.5–5.5 × 3–3.5 μ (Overh.); tubes 0.5–4 mm. long, usually shallow, less than 3 mm. long, mouths light brown; plant never reflexed. Conspicuous cystidia present and often with incrustations. On hardwoods .... *P. corticola* (Fr.) Cooke (19)
P. aneirina Fr. non Somm. ex Romell

6. Mouths of tubes averaging 1–2 to a mm. 7
6. Mouths of tubes 3 or more to a mm.; spores 7–10 × 3–4 μ
Trametes serialis Fr.
P. callosa Fr. (resupinate form)

7. Hyphae much branched; tube length 2–5 mm.; spores 6–8 × 2.5–4 μ. On hardwoods .... *T. sepium* Berkeley
7. Hyphae seldom branched; tube length 1–2.5 mm.; spores 5–6.5 × 2–3 μ; pileus, when present, very narrowly reflexed, "cinnamon brown" (Ridg.). On both hardwoods and conifers
T. variiformis Pk.

8. Spores echinulate 9
8. Spores not echinulate 10

9. Margin cobwebby; echinulate spores 2–3 × 2–4 μ. Plant effuse. On white cedar and other substrata ..... *P. candidissima* (Schw.) Cooke
P. subtilis (Schrad.) Bres.
P. hymenocystis Berk. & Br.
P. fragillina Karst. ex Romell
9. Margin not cobwebby, but narrow and well defined; echinulate spores 4–6 × 10–18 (?) μ. Plant not effuse, frequently occurring in patches on cedar branches .... *P. papyracea* (Schw.) Cooke (Pl. XIX, Fig. 1)
P. barbaeformis Berk. & Curt.

10. Tubes averaging 1 mm. or less in length (see 23, *P. lenis*, and 24, *P. medulla panis*) 11
10. Tubes averaging over 1 mm. in length 17

11. Plant with papillate pores or cup-shaped receptacles (see 15, *P. reticulata*); spores oblong-ellipsoid, 3–3.5 × 4.5–6 μ; hyphae mostly narrow, 1–2 μ wide .... *Porothelium fimbriatum* (Pers.) Fr.
11. Plant with typical pores as in the genus Polyporus or Poria. Hyphae usually more than 2 μ, at times 5 or 6 μ in diameter.... 12

12. Plant with tinge of lilac; margin tomentose; spores oblong or short-cylindric 3–5 × 1–2; hyphae flexuous, branched and quite variable in diameter, 2–7 μ. Only on hardwoods, usually on oak and chestnut .... *P. semitincta* (Pk.) Cooke[2] (Pl.XXI)
P. violacea ? E. & E.
P. fatiscens (Berk. & Rav.) Cooke in part *sensu* Weir
12. Plant not lilac-tinged in margin or in hymenium 13

13. Plant becoming irpiciform in age, pores lacerate in age; spores obovate, 2–4 × 3–6 μ. Clamp connections present, but exceedingly small .... *P. mucida* Pers.[3]
13. Plant not becoming irpiciform in age, usually with tomentose or rhizomorphic margins 14

14. Plant snow-white, fragile; spores spherical or ovoid, 3.6 × 5–6 μ
P. Vaillantii Fr.
P. mollusca Bres. *sensu* Romell
14. Plant not snow-white, but whitish yellow; spores oblong, allantoid or ellipsoid 15

15. Spores 7–9 × 2–3 μ (Romell), pores in young plant distant, resembling somewhat the structure of Porothelium
P. reticulata Fr.
P. farinella Fr. *sensu* Romell
P. espallescens var. *flavidula* K.
15. Spores shorter than 7–9 μ, and usually not more than 6 μ long 16

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[2] *P. griseo-alba* (Pk.) Sacc. has been found in Iowa. This very closely related species is characterized by its hyphae exhibiting numerous cells (abundant septation), whereas in *P. semitincta* the hyphae are divided into long cells (frequent but not abundant septation). In addition, according to Overholts (17), the spores of *P. semitincta* "are never allantoid at maturity as in *P. griseo-alba.*"

[3] Romell's extensive studies in Europe have shown that, on account of the many collections which Fries has referred to *Pol. mucidus*, it is impossible to tell what the authentic plant of *P. mucida* really is. Romell states that "none of them seem to agree with Persoon's specimen of *Polyporus mucidus.*" The unpublished plates of Fries, which are in the Riksmuseet, were examined by me in 1930. These plates show a *Pol. mucidus* which is snow-white. The illustration of the plant which appears in the unpub-

16. Plant usually on conifers; mouths becoming confluent; spores 2–3 × 3–4 μ. Clamp connections present on hyphae *P. myceliosa* Pk.[4]

16. Plant on hardwoods, usually on chestnut, oak, maple; mouths not becoming confluent, but remaining regular as in *P. medulla panis;* spores 2–4 × 4–6.4 μ. No clamp connections present or if present comparatively rare . . . . *P. tenuis* (Schw.) Cooke

17. Plant becoming sinuose-irpiciform and often hydnoid, tuberculate or nodulose (see 26, *P. subacida*) 18

17. Plant not becoming sinuose-irpiciform, tuberculate or nodulose 19

18. Spores obovate, ellipsoidal or oblong, 2–4 × 4–8 μ. Plant usually covering large portions of the sides of hardwood stumps and logs
P. ambigua Bres. (Pls. XVII and XVIII, Fig. 1)
P. salvia Berk. *sensu* Lloyd
P. salicina Murr.(?)
P. Cokeri Murr.

18. Spores cylindrically curved, allantoid, 0.7–2 × 4–7 μ. Plant on conifers . . . . *P. sinuosa* Fr. *sensu* Romel

19. Plant becoming rubescent when bruised or upon drying (see 26, *P. subacida;* 26, *P. ornata;* 21, *P. nigrescens*); watery, somewhat gelatinous when fresh and of a texture like dry skin, turning "Rood's brown" (Ridg.) to blackish and often glistening when dry; tubes 1–6 mm. long; spores 3–5–7 × 3–5 μ (Burt). Our specimens 4–5.5 × 3.5–4 μ . . . . *P. sanguinolenta* (A. & S.) Cooke

19. Plant not becoming rubescent when bruised or upon drying; remaining white, or turning yellow or buff or some other color in herbaria 20

20. Plant growing on hardwoods 21

20. Plant growing on conifers 25

21. Plant perennial, frequently exhibiting layers, as in the genus Fomes, and the new growth in particular exhibiting a receding growth habit in one-year-old or older specimens. Dried specimens separating from the substratum about the margin. Plant often showing flesh-colored tints when fresh. Thick-walled hyphae as much as 5–7.5 μ in diameter . . . . *P. nigrescens* Bres. (Pl. XVIII, Fig. 2)

21. Plant annual or perennial, but if perennial not exhibiting the receding growth habit. Hyphae usually much smaller than 5–7.5 μ in diameter 22

22. Plant fragile or soft and velvety to the touch, not cracking upon drying 23

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lished plates has been approved by Fries. The plants which are identified on the basis of the American conception of this plant are ordinarily buff (4).

[4] The chief point of difference, according to Overholts, between *P. myceliosa* Pk. and *P. fimbriatella* (Pk.) Sacc. is the presence of cystidia and the absence of cross walls and clamp connections in *P. fimbriatella.*

22. Plant not fragile and not especially soft and velvety to touch, frequently cracking upon drying; effused, frequently covering several feet of surface, usually on birch, oak, beech, chestnut, locust and sometimes other hardwoods; usually 1.5 mm. or more in thickness 24

23. Spores elliptical 3–4 × 5–6 μ (Romell); plant usually limited in growth to about 1–10 cm.; very thin, usually about 1 mm. or less in thickness. Pores angular, often hexagonal, shallow; tubes not over 1 mm. long, usually less. Plant usually not cracking upon drying. Common in the West and usually found on poplar
P. aneirina Somm. non Fr. ex Romell (Pl. XVIII, Fig. 3)
Pol. serenus Karst.

23. Small spores strongly curved so as to form a half-circle 1–2 (1–1.5) × 3–5 μ; hyphae tough, undulate, not fibulate; tubes with thin partitions; 1–1.5 mm. long. Found commonly on conifers, but it has been reported on hardwoods in the literature
P. lenis Karst. (Pl. XXII)

24. Pore mouths always entire, remaining white in herbarium specimens or varying from white to "antimony yellow" (Ridg.), not lutescent or resinous in age; tubes 0.5–3 mm. long; spores obovate, subangular, 2.5–6 × 4–7 μ (averaging 5–6 × 4.5–5); hyphae narrow, much branched. Border determinate. Plant inseparable, or separable only with difficulty ..... *P. medulla panis* (Pers.) Cooke
P. pulchella (Schw.) Cooke

24. Pore mouths fringed, hymenium whitish or light yellow, usually turning darker when bruised and pinkish buff to avellaneous in dried plants, lutescent in age; tubes when fully developed 1–9 mm. long, usually about 4 mm. long; spores 3–5 × 4–6 μ. Plant separable when fresh, coming off in sheets; on uneven surfaces inseparable 25

25. Spores subglobose or oblong-ellipsoidal, 2.5–4 μ wide, measuring 4–6 × 2.5–4 μ, but mostly 4 × 3 μ. Plant, upon drying, usually coarse, not soft and velvety to touch, frequently cracking; tubes usually appearing resinous or even somewhat hyaline at times, and in most plants ordinarily long, 1–8 mm. 26

25. Spores ellipsoidal or cylindrical, 1–2.5 μ wide; plant usually soft and fragile except in some specimens of *P. vaporaria* Fr.; seldom cracking upon drying and the tubes not appearing resinous or hyaline in the dried condition. Tubes ordinarily shorter than 4 mm. 27

26. Margin free from rounded, depressed spots; cystidia often present; plant frequently coarse and sometimes cracks upon drying. (This character is only relative.) On both hardwoods and conifers
P. subacida (Pk.) Sacc.[5]

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[5] *P. subacida* and *P. ornata* are so similar that further studies may show that the two plants are the same.

26. *Margin with rounded, depressed spots; no cystidia* (ex Overholts); plant usually coarse and conspicuously cracking upon drying. Adnate subiculum, according to Pk. On both hardwoods and conifers .... *P. ornata* (Pk.) Sacc.

27. Spores allantoid, strongly curved so as to form one half of a circle, 1–2 (–1.5) × 3–5 μ; plant soft to touch; tubes with thin partitions; hyphae tough, undulate not fibulate. On both coniferous and hardwood substrata. .... *P. lenis* Karst.

27. Spores not strongly curved so as to form one half of a circle 28

28. Spores allantoid 1.5–2 × 6 μ (Romell); pores 2–3 (–4) to a mm. Plant not soft to touch .... *P. vaporaria* Fr. (Pl. XXIII)
"*Pol. vaporarius* as understood in England is another species viz."
P. versipora Pers. — Romell (23).
P. versipora Pers. is found in cellars, hothouses, etc.[6]
P. vaporaria Fr. as understood by Romell in *Hym. of Lappl. should* be called
P. sylvestris Romell. This one is found in the "pine mountains."

28. Spores ellipsoid 1–2.5 × 3–4.5 μ; pores mostly 3 per mm.; tube length 1–3 mm.; hyphae fibulate; plant soft to touch (distinguished from *P. lenis* by the absence of the strongly curved spore character) .... *Pol. sericeomollis* Romell

Pore mouths 4 or more to a mm. (or plants having 2–5, but mostly 4 or more)

29. Spores ovoid, spherical or oblong-ellipsoidal 30

29. Spores allantoid-cylindric, mostly 1–1.5 μ wide 38

30. Plant soft and fragile, rhizomorphic, usually snow-white; spores 3.6 × 5.6 μ .... *P. Vaillantii* Fr.
P. mollusca Bres. *sensu* Romell
P. vaporaria Pers. *sensu* Bres.

30. Plant with or without pubescent margin, usually not rhizomorphic, but if rhizomorphic in exceptional specimens not fragile but leathery and with yellowish tinge 31

31. Subiculum thin, *hyaline* to blood-red and becoming *cartilaginous;* pores at first whitish but becoming red upon bruising or contact; spores 4–5.5 × 3.5–4 μ .... *P. sanguinolenta* (A. & S.) Cooke

31. Subiculum thin or thick but *never* hyaline or *cartilaginous* and pores not turning red on bruising 32

32. Subiculum indistinct, fusing at the base of the tubes in a friable *chalky* mass. Plant soon becoming arid, and rubbing off between the fingers as chalk; pore mouths glistening; thick tubes, 5.5–7 mm. long; spores 2–3 × 4–6 μ .... *P. crassa* Karst.

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[6] For me *P. versipora* Pers. is similar to *P. mucida*, but the tubes in *P. versipora* are longer.

32. Subiculum usually distinct. Plant not becoming chalky as crayon 33

33. Hymenium with flesh-colored tints. Plant perennial, stratose specimens with well-marked layers; exhibiting a receding growth, i.e. in perennial plants there is a failure of growth of the current season to cover the entire growth area of the previous year. Hyphae thick-walled; spores 3–5 μ (Overh.) .... *P. nigrescens* Bres. (18)

33. Hymenium not showing flesh-colored tints (see 35, *P. undata*). Plant not exhibiting receding growth habit; usually with much smaller hyphae than 4.5–7.5 μ (Overh.) 34

34. Plant becoming horny or crisp and hard upon drying; distinctly not coriaceous 35

34. Plant more or less coriaceous or leathery even after drying 36

35. Tubes usually long, but showing great variation, 0.5–9 mm., mostly 2–4 mm.; pore mouths fringed; abundant spores 2.5–5 × 4–6 (3.5 × 5) μ. Plant usually not separating itself from the substratum, at least to the extent that it becomes unattached from the substratum; tubes lutescent upon drying and changing to pinkish buff to avellaneous in herbaria. Usually on conifers *P. subacida* (Pk.) Sacc.

35. Tubes much shorter than 9 mm. and not varying as much as 0.5–9 mm., the majority of the tubes being 2.5 mm. long. Plant frequently separating itself from the substratum; hymenium ivory-yellow, cream-colored, becoming grayish flesh-colored upon drying. Plant forming large sheets on fallen logs, as in *P. subacida*, but on hardwoods, mostly on black ash in Michigan; spores 4–6 × 4–6 (4 × 5) μ .... *P. undata* (Pers.) Bres.

36. Pore mouths always entire, never becoming lacerate or irpiciform; hyphae much branched 37

36. Pore mouths unequal, frequently becoming fringed to lacerate; hyphae branched, but not exhibiting a fine branching system; plant usually "pinkish buff" to slightly "cinnamon buff" (Ridg.) in dried specimens and resembling *P. mucida* in color; differing from *P. mucida* chiefly by having longer tubes; spores 4–6 × 3–4 μ (Romell) .... *P. versipora* Pers. *sensu* Romell

37. Plant leathery, yellowish tinged and somewhat *rhizomorphic;* tubes usually short; spores 3–5 (4.5 × 3) 3–4.5 μ. Most frequently found on sticks and slash which still retain their bark *P. tenuis* (Schw.) Cooke

37. Plant leathery at times or more or less hardened, white in herbarium specimens or varying from white to "antimony yellow" (Ridg.) in the typical *P. pulchella* form; tubes 0.5–3 mm. long. Plant inseparable or separable only with difficulty; not rhizomorphic, usually with a well-defined border; spores 2.5–6 × 4–7 (5–6 × 4.5–5) μ. On logs and planks ...... *P. medulla panis* (Pers.) Cooke
P. pulchella (Schw.) Cooke

38. Plant soft with velvety feeling when touched, snow-white or yellowish tinged (except in 43, *P. subfuscoflavida* Fr., which is usually ashy in color) 39

38. Plant not particularly soft and distinctly not velvety when touched, and not snow-white or slightly yellowish, but ashy, grayish white or greenish or slightly pinkish 42

39. Plant white, but pores more or less sulphurous within; spores 4–6 × 1–1.5 μ .... *P. xantha* var. *calcea* (Lind.) Romell

39. Plant snow-white, at least when fresh and usually remaining so, but if change in color is noted, plant turns slightly brownish from drying and is not sulphurous 40

40. Spores biguttulate 41

40. Spores not guttulate .... *P. xantha* Lind. *sensu* Romell (Pl. XX)
P. vulgaris Fr. (Romell, *Hym. of Lappl.*, not of 1926 Remarks. See 41, *P. vulgaris* in key)
P. flava K.[7] ex Romell(?)
P. selecta K. ex Romell(?)

41. Spores usually small, allantoid, 3–3.5 × 1 μ, sometimes 4–5 × 2 μ, and very strongly curved, varying from strict allantoid to new-moon-shaped; the broadest portion of the spore at the center and narrow toward the ends — or even comma-shaped, i.e. about the shape of half of a new moon. Plant soft .... *P. lenis* Karst.

41. Spores 4–6 × 1–1.5 μ, allantoid, but not distinctly curved and new-moon-shaped .... *P. vulgaris* Fr. *sensu stricto* ex Romell, non Bresadola. Bresadola's *P. vulgaris sensu stricto* is *P. byssina* Pers.[8]
P. luteoalba Karst. *sensu* Bresadola ex Romell(?)
P. biguttulata Romell ex Romell

42. Pores exhibiting a slightly greenish cast, "deep olive buff" to "old gold" (Ridg.); pores 4 or more to a mm.; tubes mostly 0.5–1 mm. long; spores cylindrical 3–4.5 (6 × 1) –1.5–2.5 μ. On hardwoods (based largely upon specimens Herb. Berk., 1879)
P. viridans B. & Br.
P. inconstans Karst. *sensu* Bourdot et Galzin (5)

42. Pores exhibiting a pinkish cast, or pinkish cream color, or ashy-cinereous 43

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[7] *P. flavicans* K., according to Romell, is a softer and more fragile species, with tender, fibulate hyphae and generally irregular, lacerated pores. The specimen of *P. flavicans* which was studied in Stockholm is a light yellow plant, with spores measuring 3–5 × 1.5–2 μ.

[8] *P. byssina* has not been found in the region of the Lake States. Romell states ("Remarks on Some Species of Polyporus") that it is rare in Sweden, though it may be frequent in southern countries. "One could believe it to be a white form of *P. eupora* Karst., if it were not microscopically distinct" (having no cystidia). As to the spores, it differs only slightly though some specimens have the spores more oblong (especially those on Alnus).

43. Plant margins more or less definite and neither felty nor soft, rather thin; ashy or pinkish buff; spores 4 × 1 μ. Very frequently found on spruce branches which have retained the bark. Hyphae of the subiculum finely incrusted ...... *P. subincarnata* (Pk.) Murr.

43. Plant margins indefinite and thick, felty to touch or distinctly cottony; spores 4–5 (4 × 1) 1–2 μ. Very frequently found on decorticated logs and also on planks and associated with a brown cubical rot .... *P. cinerescens* Bres.[9]
P. subfuscoflavida Fr. ex Romell.

PORIAS ASHY, CINEREOUS, SMOKY OR EVEN BLACKISH

44. Fruiting-body ashy, cinereous, smoky or even blackish 45

44. Fruiting-body not white, whitish, cream-colored, ashy, cinereous or blackish, but flesh-tinted, pinkish, red, purple, yellow or brown (for olive or greenish plants see 42, *P. viridans*, and 46, *P. incrassata*) 50

45. Spores dark colored, dusky olive or blackish 46

45. Spores hyaline 47

46. Plant turning olive brown or blackish upon drying, but a dirty whitish color, sometimes yellowish tinged, when fresh. Pore mouths 1–3 per mm.; tubes unequal and ultimately becoming brittle and easily pulverized between the fingers; hyphae 2.5–3 μ in diameter; spores 10–12 × 6–7.5 μ (Burt). On conifers. Common in the South on building timbers ... *P. incrassata* (Berk. & Curt.) Burt

46. Plant always sooty or brownish black; tubes not readily pulverized between the fingers; pore mouths 4–6 to a mm.; tubes 1–5 mm. long; spores 7 × 4.5 μ (Murr.). On hardwoods ..... *P. nigra* Berk.

47. Plant ashy or grayish white, with broad sterile tomentose margin and exhibiting a cottony mycelial growth in the crevices of the substratum, particularly in badly decayed wood; pore mouths 3–6, mostly 4–6 to a mm.; spores 4–7 × 2–2.5 μ. On conifers, particularly on western conifers .... *P. cinerescens* Bres.[10]
P. subfuscoflavida Fr. ex Romell

47. Plant ashy or grayish white, but not with broad sterile tomentose margin. Margin definite. Plant not exhibiting a cottony mycelial growth in the crevices of the substratum 48

Spore measurements are recorded as 3.5–4 × 2–3 μ for a specimen which I studied in Stockholm.

[9] *Pol. subfuscoflavidus*, according to Romell, is the one which Bresadola has called *P. cinerescens*. Romell says: ". . . nevertheless I think that Bresadola's name ought to be used, as it is more appropriate than that of Rostkovius, whose picture is, moreover, dubious."

[10] *P. subvincta* has a broad margin which is felty in texture. The margin of the type specimen which I examined at Kew measures about 6 mm. This plant, which was from Berkeley's herbarium, is now "light vinaceous cinnamon" (Ridg.). The tubes are 5–6 mm. long, 6–8 to a mm. The plant is thick and resembles *P. subacida*, but the tubes are much smaller and are not lutescent. *P. subvincta* has not been found in the region of the Great Lakes.

48. Plant forming large sheets over substratum and becoming somewhat horny in herbarium; often turning dark gray upon drying, but "ivory-yellow" (Ridg.) or yellow cream-colored when fresh; pore mouths 4–5 to a mm.; tubes 1–4 mm. long; hyphae 3–5 μ wide *P. undata* (Pers.) Bres.
48. Plant not forming large sheets over substratum and not becoming horny in herbarium.. 49

49. Plant often persisting for as much as 3 or 4 years, and the new growth exhibiting a receding growth habit, frequently in orbicular patches. Dried specimens separating from the substratum about the margin. Pore mouths 5–6 to a mm.; hymenium often showing flesh-colored tints when fresh; thick-walled hyphae as much as 5–7.5 μ in diameter; spores globose, 3–5 μ (Overh.) .... *P. nigrescens* Bres.
49. Plant annual, and not exhibiting a receding growth habit; ashy-cinereous. Pore mouths 2–4, mostly 2–3 to a mm.; hyphae mostly 2–2.5 μ in diameter .... *P. cinerea* [11]

YELLOW PORIAS

50. Fruiting-body yellow or yellowish, not white, cream-colored, ashy, cinereous or blackish 51
50. Fruiting-body flesh-colored, pinkish, red, purple or brown, not yellow or yellowish, white, cream, ashy, cinereous or blackish 72

51. Pore mouths 1–3 to a mm., or plants having 3–4, but not more than 4, usually 3 or fewer than 3 52
51. Pore mouths 4 or more to a mm., or plants having 2–5, but mostly 4 or more 61

52. Yellowish plant turning dark red or purple when bruised or upon drying 53
52. Yellowish plant not turning dark red or purple when bruised or upon drying 55

53. Plant hard and bony upon drying, "pinkish cinnamon" to "russet" (Ridg.) in herbaria. Spores ellipsoidal or nearly globose or ovoid, 3.5–5 × 2.5 μ. Common on chestnut .... *P. mutans* Pk.
53. Plant not hard and bony upon drying. Spores cylindric or allantoid 54

54. Spores cylindrical, curved, at least more than one μ broad, 6–7–9 × 2–2.5 μ. Plant at first white or yellowish subochraceous, later purplish or rose, then reddish purple or blackish purple; pores 2–4 to a mm. with very thin walls; tubes short, 0.5 mm.; border of plant

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[11] It is a well-known fact that *P. cinerea* is imperfectly understood. There is no type specimen available and the name *P. cinerea* might very well be discarded along with many other plant names. I have included the general American conception of this plant in the key, but it should be emphasized that it is really impossible to tell just what was meant by its name. This poria resembles *P. attenuata* in general form, but not in color.

usually narrow-pubescent, white or pinkish; hyphae 2–3–9 μ often incrusted, clamp connections none or very rare; basidia narrow 9–15–24 × 3–5–6 μ (Bourdot and Galzin). On hardwoods *P. purpurea* Fr.

54. Spores narrow, probably not more than one μ broad (spores probably 4–5 × 1 μ Overh.). Plant at first yellowish or subochraceous, later vinaceous cinnamon or onion-skin pink or darker ("diamine brown" and "claret brown" [Ridg.]); tubes short, 0.5 mm. or less; pore mouths in type mostly 3–4 to a mm.; border 1 cm. wide or wider, "vinaceous cinnamon" (Ridg.); hyphae often incrusted; clamp connections rare. On conifers *P. mutans* var. *tenuis* Pk.

55. Spores colored. Plant turning olive-brown or blackish upon drying, but a dirty whitish color, sometimes yellowish, when fresh
P. incrassata (Berk. & Curt.) Burt
P. atrosporia Ames (1)

55. Spores not colored. Plant not turning olive-brown or blackish upon drying 56

56. Spores allantoid, strongly curved so as to form one half of a circle 1–2 (1.5) × 3–5 μ. Plant tinted yellowish only at times, mostly whitish or white, soft to touch . . . . *P. lenis* Karst.

56. Spores mostly globose or if ellipsoidal not strongly curved so as to form one half of a circle. Plant not particularly soft to touch (except 60, *P. albolutescens* and *P. vitellina*). Dried plants decidedly yellow or yellowish except 58, *P. subacida,* which is sometimes tinted yellowish; and 59, *P. myceliosa,* which is warm buff to clay color when dry 57

57. Mycelium much branched; pores regular. Plant somewhat coriaceous, deep chrome-yellow when fresh. Spores 4–6 × 4 μ. Common on western conifers, sometimes on hardwoods, such as poplar
P. xantholoma (Schw.) Cooke?[12]
(Pl. XXVI)

57. Mycelium not finely branched, pores not regular, and plant not coriaceous 58

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[12] This plant is closely related to *P. medulla panis,* but is characterized by the deep chrome yellow when fresh. This chrome yellow is distinct from the antimony yellow of the *P. pulchella* Schw., which is listed earlier in the key as *P. medulla panis.* The Swedish interpretation of *P. versipora* Pers. ex Romell, non Bres., is broad enough to include this American plant as a variety of *P. versipora* Pers. It seems to me that if the plant is to be a variety of anything it is more nearly related to *P. medulla panis* than it is to *P. versipora* and that it should be a variety of *P. medulla panis* if it is not considered to be *P. xantholoma* (Schw.) Cooke. Dr. L. O. Overholts in a private communication suggests *P. xantholoma* as a possible name. It is stated in his "Species of Poria Described by Schweinitz" that "all of the characters (of *P. xantholoma*) are typical of the bright-colored form of P-*medulla panis,* to which there is no question this plant should be referred."

58. Tubes usually long, but showing great variation, 0.5–9 mm., mostly 2–4, or if tubes are shorter than 2–4 mm.; plant not rhizomorphic — in fact, never rhizomorphic; spores 2.5–5 × 4–6 (3.5 × 5) μ *P. subacida* (Pk.) Sacc.

58. Tubes usually much less than 2 mm. Plant usually rhizomorphic .. 59

59. Plant bright-colored, yellow or brownish yellow. Subiculum "Naples yellow" to "antimony yellow" (Ridg.); pores present only on part of well-formed soft subiculum and not occupying entire surface 60

59. Plant not bright-colored, not definitely yellow or brownish yellow, but warm buff-clay color in herbaria, pale yellow when fresh. Tubes shallow, 0.5–1 mm., but mostly 0.5 mm. or less in length; pore mouths 3–4 to a mm., mostly 3 .... *P. myceliosa* Pk.

60. Subiculum cobwebby to felty, "Naples yellow" to "antimony yellow" (Ridg.); tubes remaining in position, as is common in other porias, and short, 0.5–1 mm. in length, mostly 0.5 mm., but quite well formed and distinct, drying light ochraceous buff to tawny, mostly tawny; mouths 2–4, mostly 3 to a mm. On conifers *P. albolutescens* Romell

60. Subiculum thin, soft, but not particularly felty, "Marguerite yellow" (Ridg.); tubes quite fragile and delicate, 0.5 mm., mostly less than 0.5 mm. in length and often appearing only as folds on the thin subiculum, drying to "Isabella color" (Ridg.); mouths 2–3 to a mm.; spores strongly curved, 2 × 4–5.5 μ (mostly 2 × 4 μ) *P. vitellina* (Schw.) Cooke

61. Plant yellow or yellowish when fresh, turning dark red or purple when bruised or upon drying 62

61. Yellowish plant not turning dark red or purple when bruised or upon drying 65

62. Plant hard and bony upon drying; dried colors of plant distinctive, "pinkish-cinnamon" to "russet" (Ridg.) in herbaria; spores ellipsoidal, or nearly globose, or ovoid 3.5–5 × 2.5 μ. Common on chestnut .... *P. mutans* Pk.

62. Plant not particularly hard and bony upon drying; spores cylindrical or allantoid 63

63. Spores at least more than one μ broad. Plant at first white or yellowish subochraceous, later pinkish or rose, then reddish purple or blackish. Pores 2–4 to a mm., with very thin walls; tubes short, 0.5 mm.; border of plant usually narrow-pubescent, white or purplish; hyphae 2–3–9 μ, often incrusted; clamp connections none or very rare; basidia narrow 9–15–24 × 3–5–6 μ (Bourdot and Galzin). On hardwoods .... *P. purpurea* Fr.

63. Spores narrow, not more than 1 μ broad (spores probably not more than 1 μ in *P. mutans* var. *tenuis*) 64

64. Pore mouths averaging 3–4 to a mm.; mouths "vinaceous cinnamon," "onion-skin pink," "carob brown" (Ridg.) when dry; tubes scarcely 0.5 mm. long. Type collection on spruce. Not common *P. mutans* var. *tenuis* Pk.

64. Pore mouths averaging 4–6 to a mm.; mouths "orange cinnamon" to "hazel" or "seal brown" (Ridg.) when dry; tubes 0–5 to 1.5 mm. long; spores 4–5 × 1 μ. On both hardwoods and conifers. Common .... *P. spissa* (Schw.) Cooke
P. laetifica (Pk.) Sacc.

65. Spores allantoid. Plant soft to touch, whitish or sulphurous, not deep yellow 66
65. Spores globose. Plant not particularly soft to touch (except *P. albolutescens* and *P. vitellina*); mostly yellow, or if whitish or sulphurous does not possess allantoid spores 67

66. Plant sulphurous. Spores not strongly curved, 4–6 × 1–1.5 μ (Romell) See 40 .... *P. xantha* Lind.
P. vulgaris var. *calcea* (Lind.) Romell
66. Plant whitish. Small spores strongly curved so as to form one half of a circle, 1–2 (1.5) × 3–5 μ .... *P. lenis* Karst

67. Subiculum indistinct, fusing at the base of the tubes in a friable chalky mass. Plant soon becoming arid and rubbing off between the fingers as chalk; tubes long, 5.5–7 mm.; pore mouths 5 to a mm., glistening, regular; spores 2–3 × 4–6 μ; mycelium not finely divided. On conifers .... *P. crassa* Karst.
67. Subiculum usually distinct. Plant not becoming chalky as crayon (but see 24, *P. medulla panis* and the forms *P. pulchella* and *P. xantholoma,* which sometimes exhibit a chalkiness); mycelium finely divided or, seldom, branched 68

68. Plant becoming horny upon drying and frequently separating itself from the substratum; hymenium ivory-yellow, cream-colored, becoming grayish flesh-colored upon drying. Plant forming large sheets on fallen hardwood logs, mostly black ash in Michigan
P. undata (Pers.) Bres.
68. Plant not becoming particularly horny upon drying and not separating itself from the substrata 69

69. Plant leathery or tough when fresh; tubes entire, mostly circular or subcircular, and usually thick-walled; pore mouths mostly 4 or more to a mm. 70
69. Plant not leathery tough when fresh — at least not the tubes (subiculum may be felty or tough); tubes mostly angular, thin-walled, drying light ochraceous-buff to tawny, mostly tawny; pore mouths 2–4, mostly 3 to a mm.; subiculum "Naples yellow" to "antimony yellow" (Ridg.) .... *P. albolutescens* Romell

70. Plant exhibiting a rhizomorphic tendency, seldom cracking upon drying, i.e. it remains coriaceous and somewhat leathery; spores 3–5 (4.5 × 3) 3–4.5 μ; hyphae usually much branched
P. tenuis (Schw.) Cooke[13]
P. omoema Berk.

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[13] *P. tenuis* Schw. is closely related to the yellow form of *P. medulla-panis* frequently designated *P. pulchella* Schw. *P. omoema* E. & E., non Berk., has

70. Plant not exhibiting a rhizomorphic tendency; frequently cracking upon drying 71

71. Plant mostly deep chrome-yellow when fresh. Spores 4–6 × 4 μ. Common on western conifers and sometimes on hardwoods such as aspen .... *P. xantholoma* (Schw.) Cooke? [14]
71. Plant mostly "antimony yellow" to "buff yellow" (Ridg.) to apricot yellow to white or whitish when fresh. Spores 3–3.5 × 4.5–6 μ. Common in the Middle West and East on oak and locust
P. medulla panis Fr.
P. pulchella Schw.[15]
P. xantholoma (Schw.) Cooke? [14]

RED PORIAS

72. Fruiting-body pink, flesh-colored, red or purple, not white, cream-colored, ashy, blackish, yellow or yellowish (at least not yellow or yellowish in dried specimens) 73
72. Fruiting-body brown, not pink, flesh-colored, red or purple, white cream-colored, ashy, blackish, yellow or yellowish (to be continued) ....

73.[16] Pore mouths "orange-buff" (Ridg.), or yellowish, changing to a dark or to a "vinaceous cinnamon," "onion-skin pink" (Ridg.) or darker when bruised or dried 74
73. Pore mouths not orange or yellowish [17] at first, but pink, flesh-colored, red or purple 80

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been considered by Bresadola a variety of *P. pulchella*. On the other hand, specimens at Kew show that Bresadola considered *P. omoema* Berk. & Curt. a synonym for *P. subacida*. Bresadola's broad interpretation of *P. subacida* has not been accepted in this key. *P. tenuis* exhibits rhizomorphic tendencies not only in nature, but also in my cultures (4). *P. medulla panis* and *P. subacida* are not rhizomorphic. At Kew *P. tenuis* Herb. Hookerianum and also the *P. tenuis* Herb. Mycol. M. C. Cooke are not the same *P. tenuis* described in this key. One specimen at Kew, Herb. Berk. 1879, which is marked in pencil *Pol. tenuis* Schw. *Cincinnati*, has been labeled "*Irpex tulipiferae* — very young," by Bresadola.

[14] "All of the characters are typical of the bright-colored form of *P. medulla panis*, to which there is no question this plant should be referred" (20).

[15] *P. pulchella* Schw. is the yellow form of *P. medulla panis*. See also 57, *P. xantholoma*.

[16] In order to be certain of determinations of the porias I believe that one must study the fresh plant. If one does not have notes on the fresh material, it will then be necessary to run through both sections of the key at this point.

[17] For plants straw-colored when fresh, but sometimes changing to reddish brown or brown upon drying, see 87, *P. rixosa*.

74. Pore mouths 1–3 to a mm., or plant having 3–4, but not more than 4, and usually 3 or fewer than 3 75
74. Pore mouths 4 or more to a mm., or plant having 2–5, but mostly 4 or more 77

75. Plant hard and bony upon drying, pinkish cinnamon to russet in herbaria; spores ellipsoidal or nearly globose or ovoid 3.5–5 × 2.5 μ. Common on chestnut .... *P. mutans* Pk.
75. Plant not hard and bony upon drying; spores cylindric or allantoid 76

76. Spores cylindrical, curved, at least more than one μ broad, 6–7–9 × 2–2.5 μ. Plant at first white or yellowish subochraceous, later purplish or rose, then reddish purple or blackish purple; pores 2–4 to a mm., with very thin walls; tubes short, 0.5 mm.; border of plant usually narrow-pubescent, white or pinkish; hyphae 2–3–9 μ, often incrusted; clamp connections none or very rare; basidia narrow, 9–15–24 × 3–5–6 μ (Bourdot and Galzin). On hardwoods *P. purpurea* Fr.
76. Spores narrow, probably not more than 1 μ broad (spores probably 4–5 × 1 μ Overh.) Plant at first yellowish or subochraceous, later "vinaceous cinnamon" or "onion-skin pink" (Ridg.) or darker ("diamine brown" and "claret brown" [Ridg.]); tubes short, 0.5 mm., or less; pore mouths in type mostly 3–4 to a mm., border 1 cm. wide or wider, "vinaceous cinnamon" (Ridg.); hyphae often incrusted; clamp connections rare. On conifers *P. mutans* var. *tenuis* Pk

77. Plant hard and bony upon drying, dried colors of plant distinctive, pinkish cinnamon to russet in herbaria; spores ellipsoidal, or nearly globose, or ovoid 3.5–5 × 2.5 μ. Common on chestnut *P. mutans* Pk.
77. Plant not particularly hard and bony upon drying; spores cylindrical or allantoid 78

78. Spores at least more than 1 μ broad. Plant at first white or yellowish subochraceous, later pinkish or rose, then reddish purple or blackish. Pores 2–4 to a mm., with very thin walls; tubes short, 0.5 mm.; border of plant usually narrow-pubescent, white or purplish; hyphae 2–3–9 μ, often incrusted; clamp connections none or very rare; basidia narrow, 9–15–24 × 3–5–6 μ (Bourdot and Galzin). On hardwoods .... *P. purpurea* Fr.
78. Spores narrow, not more than 1 μ broad (spores probably not more than 1 μ in *P. mutans* var. *tenuis*) 79

79. Pore mouths averaging 3–4 to a mm.; mouths "vinaceous cinnamon," "onion-skin pink," "carob brown" (Ridg.) when dry; tubes scarcely 0.5 mm. long. Type collection on spruce. Not common .... *P. mutans* var. *tenuis* Pk.
79. Pore mouths averaging 4–6 to a mm.; mouths "orange cinnamon" to "hazel" or "seal brown" (Ridg.) when dry; tubes 0.5 to 1.5 mm. long; spores 4–5 × 1 μ. On both hardwoods and conifers.
P. spissa (Schw.) Cooke
(Pl. XXIV, Fig. 2)
P. laetifica (Pk.) Sacc.

80. Whitish plant becoming rubescent when bruised or upon drying. Pores 3–6 to a mm. Plant watery, later turning blackish; tubes 1–6 mm. long; spores 3–5–7 × 3–5 μ (Burt); 4–6 × 1.5–2 μ (Rea, 22) .... *P. sanguinolenta* A. & S.

80. Plant pinkish or red, not becoming rubescent because of bruising or upon drying 81

81. Subiculum whitish or light pinkish and of the same color as the margin, not dark red, purple or blackish purple of the tubes; pores meruloid, 3–4 to a mm.; tubes gelatinous; spores 3–7 × 1–1.5 μ (Bourdot and Galzin). On conifers, mostly spruce in Michigan
P. rufa Schr. (Pl. XXIV, Fig. 1)
P. taxicola (Pers.) Bres.(?)
P. haematoda Rostk.[18]

81. Subiculum of about the same color as that of the tubes; pores not meruloid and tubes not gelatinous 82

82. Spores globose, ellipsoidal or subglobose 83

82. Spores allantoid, cylindrical, elongate or oblong 85

83. Plant becoming horny upon drying; frequently separating itself from the substratum. Hymenium ivory-yellow, cream-colored, often becoming grayish flesh-colored upon drying. Plant forming large sheets on fallen logs, mostly black ash in Michigan; spores 4–6 × 4–6 μ .... *P. undata* (Pers.) Bres.

83. Plant not becoming horny upon drying and usually not forming large sheets on fallen logs 84

84. Plant annual, thin, usually less than 1 mm. Tubes short, usually less than 0.5 mm., "vinaceous buff" (Ridg.), avellaneous or light pinkish; not layered and not exhibiting a receding growth habit; pore mouths 5–6 to a mm.; spores 3–4 × 2–3 μ (Overh.); incrusted cystidia present .... *P. eupora* (Karst.) Cooke
P. attenuata (Pk.) Cooke (Pl. XIX, Fig. 2)
P. nitida Pers.(?) *sensu* Romell
P. Blytii Fr. in part *sensu* Romell;[19] also see 86, *P. rixosa* Karst.
P. rhodella Fr.(?) *sensu* Romell
P. micans Ehr.(?) *sensu* Romell

84. Plant perennial, not thin; frequently becoming over 1 cm. in thickness; flesh-colored when fresh, but darkening upon drying; often exhibiting several layers and a receding growth habit in successive years; pore mouths 5–6 to a mm.; spores 3–5 μ (Overh.). No cystidia .... *P. nigrescens* Bres.

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[18] It has been suggested by Romell and other Scandinavian investigators that this plant may be a resupinate form of *Pol. dichrous*.

[19] According to Romell, Bresadola, lured by the fact that *Pol. rixosus* Karst. and *Pol. Blytii* Fr. have similar cystidia, considers one a variety of the other. Romell holds that the two plants are really distinct, because of the different colors and the different spores.

85. Tubes shallow, mostly 0.5 mm. long or less 86
85. Tubes not shallow, mostly 1 mm. long or longer 89

86. Plant margins actually straw-colored when fresh, but tubes pale brick, rusty fawn; spores 2.5–4 × 0.5–1 μ (Romell)
P. rixosa Karst.
P. incarnata Fr.(?) *sensu* Romell
P. emollita Fr. *sensu* Bourdot et Galzin
P. collabens Fr. *sensu* Bourdot et Galzin
P. Blytii Fr. (in part *P. rixosa* Karst. and in part *P. eupora* Karst. *sensu* Romell)

86. Plant margins not straw-colored but whitish or tinged pinkish or lilac in fresh specimens; occasionally rhizomorphic 87

87. Plant on conifers, commonly spruce in Michigan, but found on several different coniferous genera. Plant margins frequently separating from the substratum; tubes somewhat incarnate when fresh, becoming light buff in dried specimens; hymenium cracking upon drying; spores 4–5 × 1 μ ... *P. subincarnata* (Pk.) Murr. (Pl. XXV)
P. attenuata var. *subincarnata* Pk.

87. Plant on hardwoods, commonly on oak; although separable does not separate itself from the substratum at the margins 88

88. Spores oblong or short-cylindric, 1–2 × 3–5 μ; basidia always arising at the terminal ends of hyphal strands .... *P. semitincta* (Pk.) Cooke

88. Spores allantoid at maturity, 4–5 × 1 μ; origin of basidia not only at the terminal ends of hyphal strands, but frequently several basidia may arise from the side of a hyphal strand (Overh.)[20]
P. griseo-alba (Pk.) Sacc.

89. Plant ashy, slightly flesh-colored, margins indefinite and thick, felty to touch or distinctly cottony; tubes 1–4, mostly 1–2 mm. long; spores 4–5 (4 × 1) 1–2 μ. Very frequently found on decorticated logs and also on planks and associated with a brown cubical rot .... *P. subfuscoflavida* Fr. ex Romell
P. cinerescens Bres.

89. Plant rosy-fulvous, margins conspicuous, but narrow in age and therefore not felty to touch or cottony; tubes regular, up to 5 mm. long; spores 5.5 × 2.5 μ (Murr.) .... *P. Dodgei*[21] Murr.
P. placenta Fr.(?)

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[20] I have followed Overholts in the interpretation of this plant. It is not so common in the region of the Great Lakes as is the allied *P. semitincta*.

[21] I have not collected this plant in this region. Because the type specimen has been divided into separate small fragments it is exceedingly difficult to interpret this plant. The type specimen was collected near Algoma, Wisconsin. *P. placenta* Fr. has larger spores (6–8 × 2–3 μ) than those given by Murrill for *P. Dodgei*, namely 5.5 × 2.5 μ (14). Nevertheless, the two plants are very similar and further study may show that they are identical. The specimen of *P. placenta* studied in Stockholm is salmon-pink. The texture is coriaceous, somewhat like that of *P. medulla panis*. The pore mouths are 2–3 to a mm.

'LIST OF RESUPINATE PLANTS FROM THE REGION OF THE GREAT LAKES

An asterisk (*) after a key number refers to a footnote; a dagger (†) indicates both text and footnote

(The brown forms of porias are not listed in this paper.)

	Key No.
Fomes annosus Fr.	5
Polyporus serenus Karst.	23
Pol. sericeomollis Romell	28
Poria albolutescens Romell	60, 69
P. ambigua Bres.	18
P. aneirina Fr., non Somm. ex Romell	5
P. aneirina Somm., non Fr. ex Romell	23
P. atrosporia Ames	55
P. attenuata (Pk.) Cooke	84
P. attenuata var. subincarnata Pk.	87
P. barbaeformis Berk. & Curt.	9
P. biguttulata Romell ex Romell	41
P. Blytii Fr.	84,† 86
P. byssina Pers.	41†
P. callosa Fr.	6
P. candidissima (Schw.) Cooke	9
P. cinerea (Schw.) Cooke	49†
P. cinerescens Bres.	43,† 47, 89
P. Cokeri Murr.	18
P. collabens Fr. *sensu* Bourdot et Galzin	86
P. corticola (Fr.) Cooke	5
P. crassa Karst.	32, 67
P. Dodgei Murr.	89
P. emollita Fr. *sensu* Bourdot et Galzin	86
P. espallescens var. flavidula Karst.	15
P. eupora (Karst.) Cooke	41,* 84
P. farinella Fr. *sensu* Romell	15
P. fatiscens (Berk. & Rav.) Cooke, in part; *sensu* Weir	12
P. fimbriatella (Pk.) Sacc.	16*
P. flavicans Karst.	40*
P. flava Karst. ex Romell	40
P. fragillina Karst. ex Romell	9
P. griseo-alba (Pk.) Sacc.	12,* 88
P. haematoda Rostk.	81
P. hymenocystis Berk. & Br.	9
P. incarnata Fr.(?) *sensu* Romell	86
P. inconstans Karst. *sensu* Bourdot et Galzin	42
P. incrassata (Berk. & Curt.) Burt	46, 55
P. laetifica (Pk.) Sacc.	64, 79
P. lenis Karst.	23, 27, 41, 56, 66
P. luteoalba Karst. *sensu* Bresadola ex Romell	41
P. medulla panis (Pers.) Cooke	24, 37, 57,* 70,* 71†
P. micans Ehr. *sensu* Romell	84
P. mollusca Bres. *sensu* Romell	14, 30
P. mucida Pers.	13†
P. mutans Pk.	53, 62, 75, 77
P. mutans var. tenuis Pk.	54, 64, 76, 79
P. myceliosa Pk.	16,† 59
P. nigra Berk.	46
P. nigrescens Bres.	21, 33, 49, 84
P. nitida Pers.(?) *sensu* Romell	84
P. omoema Berk.	70†
P. ornata (Pk.) Sacc.	26†
P. papyracea (Schw.) Cooke	9
P. placenta Fr.	89
P. pulchella (Schw.) Cooke	24, 37, 57,* 70*
P. purpurea Fr.	54, 63, 76, 78
P. reticulata Fr.	15
P. rhodella Fr.(?) *sensu* Romell	84
P. rixosa Karst.	86
P. rufa Schr.	81
P. salicina Murr.(?)	18

Key No.
P. salvia Berk. *sensu* Lloyd 18
P. sanguinolenta (A. & S.) Cooke 19, 31, 80
P. selecta Karst. ex Romell 40
P. semitincta (Pk.) Cooke .. 12, 88
P. sinuosa Fr. *sensu* Romell 18
P. spissa (Schw.) Cooke 64, 79
P. subacida (Pk.) Sacc. 26,† 35, 58, 70*
P. subfuscoflavida Fr. ex Romell 43,† 47, 89
P. subincarnata (Pk.) Murr. 43, 87
P. subtilis (Schrad.) Bres. 9
P. subvincta (Berk. & Curt.?) . 47*
P. sylvestris Romell 28
P. taxicola (Pers.) Bres. 81
P. tenuis (Schw.) Cooke 16, 37, 70†
P. undata (Pers.) Bres. 35, 48, 68, 83
P. Vaillantii Fr. 14, 30
P. vaporaria Fr. 28
P. vaporaria Pers. *sensu* Bresadola. 30

Key No.
P. versipora Pers. 28,† 28, 36, 57*
P. violacea (?) E. & E. 12
P. viridans B. & Br. 42
P. vitellina (Schw.) Cooke 60
P. vulgaris Fr. 40
P. vulgaris Fr. *sensu stricto* ex Bresadola 41
P. vulgaris Fr. *sensu stricto* ex Romell 41
P. vulgaris var. calcea (Lind.) Romell 66
P. xantha Lind. 66
P. xantha var. calcea (Lind.) Romell 39
P. xantholoma (Schw.) Cooke 57,† 71†
Porothelium fimbriatum (Pers.) Fr. 11
Trametes sepium Berk......... 7
T. serialis Fr. 6
T. variiformis Pk. 7

SOME LITTLE KNOWN AND UNKNOWN PLANTS AND PLANTS WHICH HAVE NOT BEEN COLLECTED IN THE REGION OF THE GREAT LAKES

BOLETUS CROCEUS Schw. — This plant was later referred to *P. nitida* by Schweinitz (20).

POLYPORUS ALBOCARNEOGILVIDUS Romell. — Bresadola interprets this as *Pol. micans,* which is not acceptable to Romell. The color of the specimens which I have seen of *Pol. albocarneogilvidus* reminds one of that of *Trametes subroseus.* According to Romell, *Pol. micans* in *Svensk Flora* is *Pol. albocarneogilvidus,* which was called *Pol. colliculosus* by Persoon.

POLYPORUS BELPHARISTOMA B. & Br. — *Pol. belpharistoma* belongs to the *P. mucida* group, which needs additional study before the identity of many of the described forms can be determined. There is a specimen of *Pol. belpharistoma* at the Kew Herbarium from the herbarium at Berkeley. This plant appears to be a very thin form. The entire plant is less than 0.5 mm. in thickness.

POLYPORUS CRUENTATUS Mont. = *P. spissa* (Schw.) Cooke.

POLYPORUS FLAVICANS Karst. — Although *Pol. flavicans* has not been collected in the region of the Great Lakes, it is believed that it will be found at some future time. Several collections of very closely allied plants — if they are not identical — are found here on spruce and other conifers. Romell gives the following description: "Resupinate with a narrow adpressed byssoid ciliate margin and thin fragile pore walls. Spores suballantoid, 2-guttate, 3–5 × 1.5–1.75 (–2 μ). Hyphae 2–5 μ broad, soft and fibulate, sprinkled with granules and as if coagulated, so that they are somewhat opaque.

"The species occurs in Sweden, but is not frequent. Fries referred it to *Pol. nitidus*, according to a specimen in his herbarium, but his unpublished picture with the name *Pol. nitidus* is another species, which reminds one of *Pol. aurantiacus* Rostk."

POLYPORUS INCRUSTANS Berk. & Curt. — This soft white plant, which was found "running over grass and various substances," is listed under the name *P. humilis* by Murrill (11). It is not known from this region under this name. A specimen is deposited in the herbarium at the Missouri Botanical Garden which has been labeled *Pol. incrustans* Berk. & Curt. It was collected on earth in a mushroom cellar.

POLYPORUS LUTEOALBUS Karst. — The name has been applied to several plants. Romell (24) states that "one of the specimens so named in Karsten's herbarium seems to belong to a Ptychogastric species with ellipsoidal spores (5–7 × 3–4.5)." One of the plants studied in the herbarium in Stockholm is on pine. The spores of this plant were recorded as measuring 4–4.5 × 0.5–1 μ. This was a small-pored plant with pores 5–6 to a mm. It is believed that this species will be found in the region of the Great Lakes.

POLYPORUS MICANS (Ehrenb.) Fr. — Bresadola interprets *Pol. albocarneogilvidus* as *Pol. micans*, which is not acceptable to Romell. The specimen, which I saw in Stockholm and which is probably the one that Romell refers to in his remarks, is now salmon-pink. The spores are subglobose, 4–5 × 3.5–4

μ. These are not the measurements given by Rea for *Pol. micans.* He gives 7–8 × 3 μ for the spore measurements of this species.

Polyporus pallescens Karst. — On conifers. This plant, which is often resupinate, differs, according to Romell, from *Pol. euporus* by the lack of cystidia, absence of reddish tint, and by the smaller spores. It has not been collected in this region. The plant which I saw at the Riksmuseet, Stockholm, has the general aspect of a small-pored form of *P. subacida,* but of course the spores are different. Upon drying some specimens become ashy in color.

Poria Alabamae (Berk. & Cooke). — Cooke made his description from plants collected in Florida. This plant is allied to *P. tenuis* and *P. medulla panis.* It needs additional study before one can determine what name should be applied.

Poria albirosea Murr. (14). — *P. albirosea* has not been collected in this region.

Poria Amesii Murr. (12). — The type collection was made on maple wood, Long Island, New York. This chalky white poria has not been found in the region of the Great Lakes.

Poria arachnoidea Murr. — This plant has probably been described under some other name, possibly *P. onusta* Karst. There have been no collections made in the region which have been referred to *P. arachnoidea.*

Poria argillacea (Cooke) Sacc. — The type specimen was collected in California. This plant is not now known.

Poria atrosporia Ames. — *P. atrosporia,* in my opinion, is the same as *P. incrassata* (Berk. & Curt.) Burt.

Poria aurantiaca Rostk. — See *P. aurea* Pk.

Poria aurantiopallens (Berk. & Curt.) Cooke. — This plant is not known from the region of the Great Lakes.

Poria aurea Peck. — I have examined the type specimens and find that this plant resembles *P. subacida* in general aspect, although the tubes are not so long as they commonly are in *P. subacida,* and the color is much more golden. Overholts, who has also studied the specimens at Albany, states: "The affinities of this specimen are not clear. The general appearance is somewhat that of forms of *P. subacida* or related species, but it differs in the more yellow color when fresh, the different spores, the presence of conspicuous cystidia, the diameter of the hyphae, and the presence of plant connections. It probably belongs to a different group of species." Weir (25) lists *P. aurea* Pk. under *P. aurantiaca* Rostk. This plant is not known in the region of the Great Lakes.

PORIA BEAUMONTII Berk. & Curt. — Not known in this region. Murrill suggests that it should be compared with *P. omoema.*

PORIA BOMBYCINA Fr. — The specimens which I have seen in Europe remind one of a plant bearing many of the general characters of *P. callosa* and *P. sinuosa.* The spores of the specimen seen in Stockholm are recorded as 5.5–8 × 4–4.5 μ. The pores of this species first appear as small depressions in the mycelium and later develop into tubes 1–2 mm. deep. The plant is found on conifers.

PORIA CALKINSII Murr. — Macroscopically this plant resembles *P. tenuis.* The spore measurements as given by Murrill (4 × 2.5 μ), however, are slightly different from those usually obtained for plants belonging to the group *P. pulchella* — *P. tenuis* (15).

PORIA CARYAE (Schw.) Cooke. — The type material is so meager that it is unlikely that this plant will ever be thoroughly understood. The specimens at Kew, "Herb. — Berk. — ex Herb. Schw.," are light drab. Tubes 2–3 to a mm. and 1–3 mm. long.

PORIA CHRYSOBAPHA (Berk. & Curt.) Cooke. — It is impossible to determine from the description just what this species is. The olive-yellow tubes of the ferruginous spores, as pointed out by Murrill, should, however, be characteristic.

PORIA CHRYSOLOMA Fr. — Of *Trametes abietis* Karst. Romell states: "It is not mentioned in Fries' works, unless *P. chrysoloma* is the resupinate form of it, which seems probable, though it can scarcely be demonstrated now, as authentic specimens are not saved so far as I know." *P. chrysoloma,* as interpreted by Bresadola, seems to be close to his *P. rancida* in general appearance, although the spores are slightly different.

In *P. chrysoloma* (*sensu* Bresadola) the spore measurements recorded are 5–6 × 4–4.5 μ, but in *P. rancida* Bres. the spores are given as 5–7 × 2.5–2.75 μ.

PORIA CINCINNATII Berk. — This plant is not known.

PORIA CINCTA Berk. — The plant, Herb. Berk., 1879, now at Kew, is mostly natal-brown. There are about 6–8 pore mouths to a mm. and the tubes are about 2 mm. in length. A description, evidently based upon that of Massees', is given by Rea. I am not acquainted with this plant.

PORIA CINEREA (Schw.) Cooke. — Since no known types of this plant exist, it is impossible to say just what is included under this name. It has appeared so often on specimens found in various herbaria, however, that an interpretation of the American concept of this species as developed by usage may very well be given at a later date. I have not been able to refer any of my collections to this plant.

PORIA CLATHRATA (Berk. & Curt.) Sacc. — This plant is not known. The type is from Louisiana.

PORIA COCOS (Schw.) Wolf. — There are no specimens of this fungus in the herbarium at the University of Michigan. Although fruiting-bodies of this poria have not been collected in this region, several tuckahoes from Wisconsin have come to my attention.

PORIA COKERI Murr. = *P. ambigua* Bres.

PORIA CREMOR (Berk. & Curt.) Cooke. — This poria requires additional study before its relations to other plants can be determined. The type collection is from South Carolina.

PORIA CROCIPORA (Berk. & Curt.) Sacc. — Several specimens which have been found in Wisconsin and elsewhere have been labeled *P. crocipora.* Neuman reports that the plant from Blue Mounds, Wisconsin, was identified by Bresadola. Other specimens from Blue Mounds are to be found in the Field Museum. They are deep blood-red in the hymenium and light pale yellow at the margins. Just what relation this plant has to its allied forms cannot be stated without further study. Bresadola believes that the Wisconsin plant which he labeled *P. crocipora* Berk. & Curt. is very distinct from *P.*

rufa. The pores of this particular plant are now "Hessian brown" (Ridg.). The margin is pinkish buff.

PORIA CRUSTULINA Bres. — This species was described from material collected in Washington and Montana by J. R. Weir. It has been found on *Picea Engelmanii* and *Picea sitchensis. P. crustulina* is not known from the region of the Great Lakes.

PORIA DECOLORANS (Schw.) Cooke. — Not known in this region. Overholts (21) reports that the color of the fresh plant is white but upon drying becomes smoky black. He points out that the additional characteristic features of the species are the globose spores, 5–6 μ, and the large amount of crystalline material in the tramal tissue near the bottom of the tubes.

PORIA DICHROA Bres. — This species has been collected by J. R. Weir on *Pinus contorta, Abies grandis, Tsuga heterophylla* and *Pseudotsuga taxifolia* in Idaho and Montana. *P. dichroa* is not known from the region of the Great Lakes.

PORIA DISTORTA Murr. — There have been no white or cream-colored collections made in this region which have been referred to this name.

PORIA DRYINA (Berk. & Cooke) Cooke. — This plant is probably related to, if it is not identical with, *P. subacida.* The spores of a specimen collected by Dr. E. A. Bessey on Betula in Gogebic County, Michigan, measure 4.5–5 × 3–3.5 μ.

PORIA ELACHISTA (Berk.) Cooke. — Unknown in this region.

PORIA EYREI Bres. — This plant belongs to the *P. mucida* series, a group which needs additional study before it is thoroughly understood. P. Eyrei is unknown in this region.

PORIA FAGICOLA Bres. — *P. fagicola* was described from material "ad truncos *Fagi ferrugineae,*" collected by J. R. Weir in Washington, D. C. *P. fagicola* belongs to the *P. mucida* group as interpreted by Bresadola. See *P. proxima* Bres. and No. 13, *P. mucida,* in the key. This plant is not known from the region of the Great Lakes. It differs from *P. mucida,* according to the description, by smaller spores, "4–4.5 × 2–2.5 μ," and wider hyphae, "3–9 μ."

PORIA FATISCENS (Berk. & Rav.) Cooke. — According to Weir (26), *P. fatiscens* (Berk. & Rav.) Cooke includes *P. tenella*

Berk. & Cooke, *P. semitincta* (Pk.) Cooke and *P. subviolacea* E. & E.

PORIA FAVESCENS (Schw.) Cooke. — Overholts finds that both the external and microscopic characters of this plant are similar to those of *Trametes sepium.*

PORIA FAVILLACEA (Berk. & Curt.) Cooke. — Unknown.

PORIA FIMBRIATELLA (Pk.) Sacc. — Overholts has found that the herbarium sheet at Albany contains parts of two separate collections and that there is some doubt as to the identity of the two collections. Overholts regards the specimens collected on maple at Osceola as the type. He points out that the relationships of this plant are "clearly those of *Poria myceliosa.* The chief point of difference having diagnostic value is the presence of cystidia in the former species and the absence of cross walls and plant connections."

PORIA FLAVIDA Murr. — The identity of this plant is not known. Plants which I have seen are now dirty buff, with large pores about 1 to a mm. The tubes are 1 mm. long. It is possible that this plant is actually a species of Merulius.

PORIA FULVELLA Bres. — This plant was described from material found on *Pinus contorta.* It is not known from the region of the Great Lakes.

PORIA GILVESCENS Bres. — Bourdot and Galzin list *P. sanguinolenta* Bres. as a synonym. Specimens so labeled at Kew are now of a cream flesh color. There are 4–5 tubes to a mm., which are mostly 1–2 mm. long.

PORIA GORDONIENSIS B. & Br. — The type at Kew is a very thin plant, about 0.5 mm. in thickness. The pore mouths are 2–4, mostly 4 to a mm. I do not know this white poria.

PORIA HETEROMORPHA Murr. — It is doubtful whether *P. heteromorpha* will ever be found in this region. The type was collected in Jamaica and the only specimens known from the United States were collected in Florida. Evidently this is a quite variable plant, since the hymenium may exhibit a poroid or a daedaloid appearance. I am unable to state just what relationships do exist between *Lenzites heteromorpha* and *P. heteromorpha.* I have made many collections of *L.*

heteromorpha on spruce in Norway and find that the Norwegian plant which passes under the name of *Lenzites heteromorpha* appears to be very distinct from this poria.

Poria hibernica Br. & Br. — I do not know this white plant.

Poria Holoxantha (Berk. & Curt.). — The type specimen, according to Murrill, is on oak. It is imperfectly understood. The type plant was found in Georgia.

Poria humilis (Berk. & Curt.) Murr. — Murrill lists *Pol. incrustans* Berk. & Curt. as a synonym, "not *Poria incrustans* Pers. Myc. Eur. 2 : 93. 1825." This plant is found on damp soil, grass, etc. Not known from the region of the Great Lakes.

Poria hymeniicola Murr. — There have been no collections of plants from this region which have been referred to this name.

Poria Hyperborea Berk. — Murrill states that "Cooke was perfectly correct in saying that this is merely a resupinate condition of some species of Coriolus."

Poria incarnata (Alb. & Schw.) Cooke. — *P. incarnata* is not known in this region.

Poria incerta (Pers.) Murr. — This plant is a variable one and is related to the group *Irpex deformens* — *P. mucida*. It is difficult to say just what is included under this name.

Poria indurata (Pk.) Cooke. — The type material is reported by Overholts to be sterile. I have seen the type material and found that it is impossible to determine just what plants might be included under this name. *P. indurata* is not known to me.

Poria interna (Schw.) Cooke. — Known only from the original description.

Poria Juglandina (Schw.) Cooke. — Type material too fragmentary for reference.

Poria lacerata Murr. — The type collection of this white poria was made on *Quercus alba* in Arkansas. This plant is not known from this region.

Poria leucolomea (Lev.) Cooke. — *P. leucolomea* is not known. The original description is inadequate.

Poria limitata (Berk. & Curt.) Cooke. — Not known in this region.

Poria Lindbladii (Berk.) Sacc. — A resupinate form of *Pol. floridanus* Berk., according to Murrill and others.

Poria luteoalba Karst. — According to Romell in his "Remarks," one of the specimens so named in Karsten's herbarium seems to belong to a ptychogastric species. The specimen of *P. luteoalba* Karst. ex Bresadola, which I have studied in Stockholm, is very near *P. vulgaris;* Romell seems to question whether the two plants are not the same. The spores of this latter plant are 4–4.5 × 1 μ. In the ptychogastric species Romell reports the spore measurements as 5–7 × 3–4.5 μ. This plant is very similar to some of those in my collections from Oregon.

Poria metamorphosa Fuck. — This poria is listed by Bourdot and Galzin as a form of *P. aneirina* Somm., Lapp., p. 276. The plant on apple wood, which I have seen in Stockholm ex herb. H. Bourdot, shows that the structure is similar to that of *P. aneirina.* In some respects one is also reminded of *P. sinuosa.*

Poria monticola Murr. — The type specimen was found on a decorticated log of *Pinus monticola* at Priest River, Idaho. The plants in this white group have not been studied critically and it is impossible without further research to make statements in regard to their occurrence in this region. It is frequently very difficult to separate some of these western plants from the species of the genus Trametes:

Poria nigropurpurea (Schw.) Cooke. — This plant has not been found in this region and is unknown.

Poria obducens Pers. — Considered a resupinate form of *Fomes connatus.* The name *P. obducens* has been applied to a great variety of plants, and many plants in various herbaria which belong to the *P. medulla panis* group have been labeled *P. obducens.*

Poria ochracea Murr. — Not known from the region of the Great Lakes.

Poria odora (Pk.) Sacc. — Overholts states that "The affinities of this species are in doubt. The combination of cracks present is quite unlike that found in other species of poria and the plants bear some resemblance to *Poria subacida,* but are easily distinguished by the much smaller tubes and the much different spores. It also bears a resemblance to *Poria ornata,* but the pores are smaller and the spores different . . . on decorticated trunks of spruce. Type locality: Osceola, New York. C. H. Peck. Not otherwise known to the writer."

PORIA ONUSTA (Karst.) Bres. — This more or less fragile yellow poria has not been found in this region, but in all probability will be collected at some future time. I have collected specimens on redwood in California, which, according to Romell, are very closely allied. According to Bourdot and Galzin, the spores of *P. onusta* are 5–6 × 4.5–5 μ. The plants which I have seen in Stockholm are bright yellow, as in *P. pulchella,* but the habit is more like that of *P. sinuosa.* The fragments of this species which have been received by Romell show that the plant is very soft and fragile to touch.

PORIA PANNOCINCTA Romell. — This plant, which I have seen on Betula from Kalixfors, Sweden, suggests a form of *Pol. semipilleatus* Pk. The spores as given on specimens by Romell measure 3–4.5 × 0.5 (–1) μ.

PORIA PARKSII Murr. — This plant is not known from the region of the Great Lakes.

PORIA PEREXTENSA Murr. (13). — In this region no white plants with felty or cottony margins have been referred to this name.

PORIA PINEA (Pk.) Sacc. — Burt (7) lists this species as a synonym for *P. incrassata* Berk. & Curt., a poria found frequently in the South and elsewhere on building timbers. Overholts states that the type is "on wood and bark of pine. Type locality: Selkirk, New York. C. H. Peck. Not otherwise known to the writer."

PORIA POLYPORICOLA Murr. — The type specimen was collected on a cypress log in Florida. This plant is not known from the region of the Great Lakes.

PORIA PROXIMA Bres. (6). — The type material is on trunks of *Hicoria alba,* Indiana. *P. proxima* evidently belongs to the *P.*

mucida group as interpreted by Bresadola. Bresadola states: "Videtur *Poriae mucidae* Pers. proxima et praecipue praesentia cystidiorum diversa." It seems to me that the possible variations in the plants belonging to this group are so numerous that one is unable to include them all in the key without a special study of the entire group. See No. 13 in the key.

PORIA RADICULOSA (Pk.) Sacc. — I have examined the plants at Albany and find that the type fragments are so meager that they furnish little aid in the recognition of the species. Overholts has given the best description that can be presented from these plants. He states: "The chief characteristics of the species appear to be the color, the rhizomorphic strands, and the oblong-ellipsoidal spores. The spores measure 5–7.5 μ in length and 2.5–2 μ in breadth. No cystidia are present." Overholts mentions the specimens which are referred to as *P. radiculosa* by Peck and which are in the same folder in the State Museum. He says: "Microscopic examination shows, however, that it is not the same plant though somewhat similar as far as one is able to judge."

PORIA RANCIDA Bres. — This white or pale tan coriaceous plant is very likely to be found on the coniferous stumps in the region. There are sterile specimens in my herbarium which might well be referred to this species if the spores were known and if they agreed with the description. The spores of the plant (det. Bresadola), which I have studied in Stockholm, are recorded as 5–7 × 2.5–2.75 μ. The basidia are clavate, 15–18 × 4–6 μ. This plant is on Larix. My undetermined plants are on stumps of *Pinus resinosa*. In some aspects it resembles *Trametes abietis* Karst. See *P. chrysoloma*.

PORIA RHODODENDRI (Schw.) Cooke. — Overholts states that this plant seems to be the same as *Trametes sepium*.

PORIA RIMOSA Murr. — The type collection was on a decorticated log of *Juniperus monosperma* in New Mexico. The hymenium of this plant soon cracks transversely every few millimeters. *P. rimosa* is not known from this region.

PORIA SALICINA Murr. — If *P. salicina* and *P. ambigua* Bres. are not identical, they are very closely allied.

Poria salmonicolor Berk. & Curt. — Plant less than 0.5 mm. in thickness, slightly myceloid; pores 2–3 to a mm., drying to "onion-skin pink" (Ridg.), but color changes from a "tinge of salmon" to a dull red in drying. On under side of rotten coniferous logs (pine) and, according to a note taken from the type specimen, "continuous for 2–3 feet with a thin narrow sub-tomentose margin." Murrill includes this as a synonym of *P. spissa* (Schw.) Cooke.

Poria salviae (Berk. & Curt.) Cooke. — This name is probably a synonym. Lloyd has suggested *P. ambigua.*

Poria sassafras (Schw.) Cooke. — *P. sassafras* is not known from the region of the Great Lakes.

Poria separans Murr. — No collections made in this region have been referred to this name. In general color and luster *P. separans* resembles *P. subacida.*

Poria similis Bres. — The type material is on *Populus trichocarpa,* Idaho. Bresadola states: "*Poriae corticolae* valde similis, sed sporis minoribus et praesentia cystidiorum bene distincta." According to the descriptions published by Overholts, the presence of distinct cystidia is a characteristic feature of *P. corticola.*

Poria subavellanea Murr. — The type specimen was collected on pine bark in Alabama. This pale avallaneous plant has not been found in the region of the Great Lakes.

Poria subbadia Murr. — The type specimen was collected at Auburn, Alabama, by L. M. Underwood. I have not found this salmon-colored plant.

Poria submollusca Murr. — There have been no collections made in this region which have been referred to this snow-white plant. The type was found on hickory in Louisiana.

Poria subradiculosa Murr. — This white or yellowish plant in the dry state possesses a color similar to that of *P. sinuosa* or *P. subacida.* The type specimens show distinct rhizomorphic strands which are not characteristic of *P. subacida. P. subradiculosa* is not known from the region of the Great Lakes.

Poria subrufa Ellis & Dearness. — The type specimen, according to Murrill, was collected at Granton, Ontario, on a beech log. This plant, if not the same as *P. mutans*, is very closely related to it and the allied plants.

Poria subspadicea Fr. — Not known in this region, at least under this name.

Poria subsulphurea (E. & E.) Murr. — This plant is not known from the region of the Great Lakes. Compare with 55, *P. xantholoma*.

Poria subviolacea E. & E. — Murrill states: "I find only one packet so labeled in the Ellis collection and it is practically destroyed by insects." Specimens which have been labeled *P. subviolacea* are distinctly like *P. semitincta* in general appearance. See comments on *P. fatiscens* (Berk. & Rav.) Cooke.

Poria sulphurella (Pk.) Sacc. — This plant has not been collected in the region of the Great Lakes.

Poria tegillaris Berk. — The original description of *P. tegillaris* is inadequate.

Poria terrestris (DC.) Fr. — This white plant, which becomes rufescent when bruised and then somewhat blackish, has appeared in the literature frequently. Many plants have undoubtedly been referred to this name because they were growing on the soil. I do not know this plant. Bourdot and Galzin list *P. terrestris* Pers. as a variety of *Daedalea biennis*. Reference should also be made to the *P. terrestris* to which they refer *P. mollicula* Nob. P. & Lloyd, *Myc. Not.*, p. 543, n. 40, Figure 744 — non *P. terrestris* Pers., rec. Bres. Of the plant so labeled in the Wisconsin Herbarium, Neuman states (16): "Only one specimen has been found in the state. It was growing on the ground in the greenhouse. . . . The plant was held to the ground by rhizomorphous strands which were about 8–9 cm. long and from 1–2 mm. thick. . . . The spores are subglobose about 4 μ by 3.5 μ."

Poria tomento-cincta Berk. & Rav. — According to Murrill, this type was found on oak bark in South Carolina. There is a specimen ex Herbario Ellis at Kew which was collected on a cedar log near Philadelphia. Additional study is needed before this plant is fully understood.

Poria tricolor E. & E. (Lloyd 2548). — Ex Herb. Ellis. *P.*

tricolor belongs to the *P. spissa* series. Further research is necessary before this plant is understood.

PORIA VESICULOSA (Berk. & Curt.) Cooke. — This plant is allied to *P. subacida.* Murrill mentions the fact that Peck considered it a variety of this quite variable *P. subacida.* I have collected plants in Colorado which have been tentatively referred to this plant, but this poria needs additional study before one can determine which name should be retained. Murrill lists *Pol. tenellus* Berk. & Cooke as a synonym.

PORIA VINCA Bres. — Described from the material collected on the trunks of *Abies grandis* by J. R. Weir. *P. vinca* is unknown from the region of the Great Lakes.

PORIA VIOLACEA (Fries) Cooke. — Murrill states that, "according to Bresadola, this very rare species is scarcely known by mycologists, even Fries himself confusing it with other species. The color . . . is constant, dilute-violet; subiculum exceedingly thin, tubes 2 to a mm., very short, resembling those of *Merulius;* spores 5×2.5–$3\ \mu$."

PORIA VITREA (Pers.) Fr. — The plant which I have examined at Kew is from the Herb. M. C. Cooke, 1885. It is now more or less fawn-colored and is glassy in general appearance. The tubes are somewhat hyaline and measure 2–3 mm. in length. The spores, according to Rea, are said to be "globose, ocellate, hyaline, 4 μ; or ovoid, 4–2.5 μ, Bres."

PORIA XANTHOLOMA (Schw.) Cooke. — See No. 57 in key of porias.

PORIA ZONATA Bres. — Described from material collected on *Abies grandis* by J. R. Weir. Bresadola states: "Dem *Poria radula* von Aussehen ganz gleich, aber, besonders durch Sporen, gut verschieden."

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PLATE XVII

Poria ambigua Bres. on hackberry. This is the common habit of growth of this fungus in the overflow lands of the Mississippi River. In Michigan it is more common on stumps

PLATE XVIII

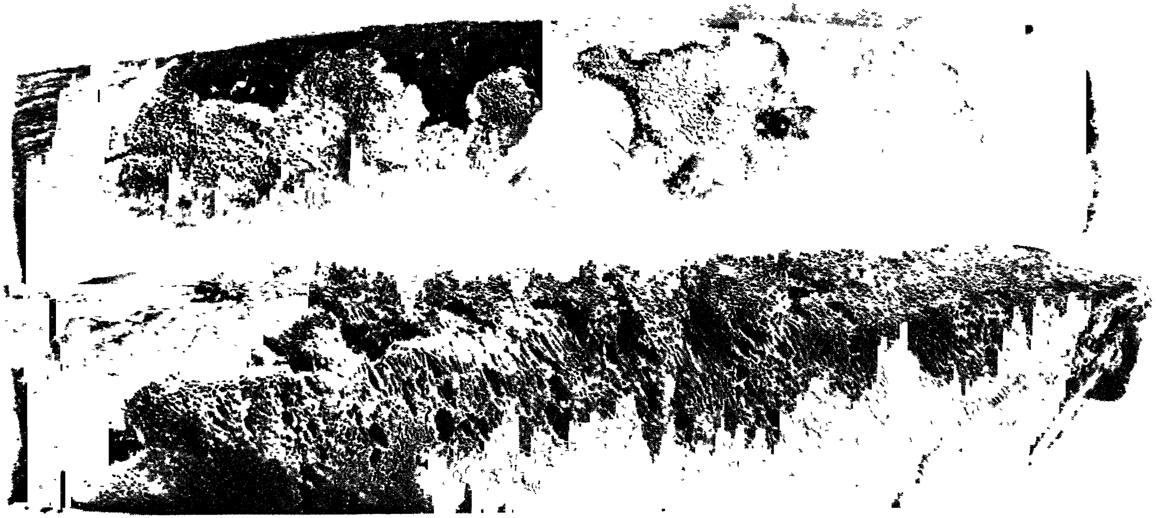


FIG. 1. *Poria ambigua* Bres. on beech. Turkey Run, Indiana State Park

FIG. 2. *Poria nigrescens* Bres. Note the receding growth habit and the distinct layers of tubes

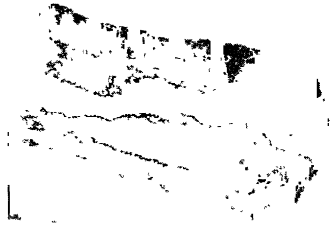


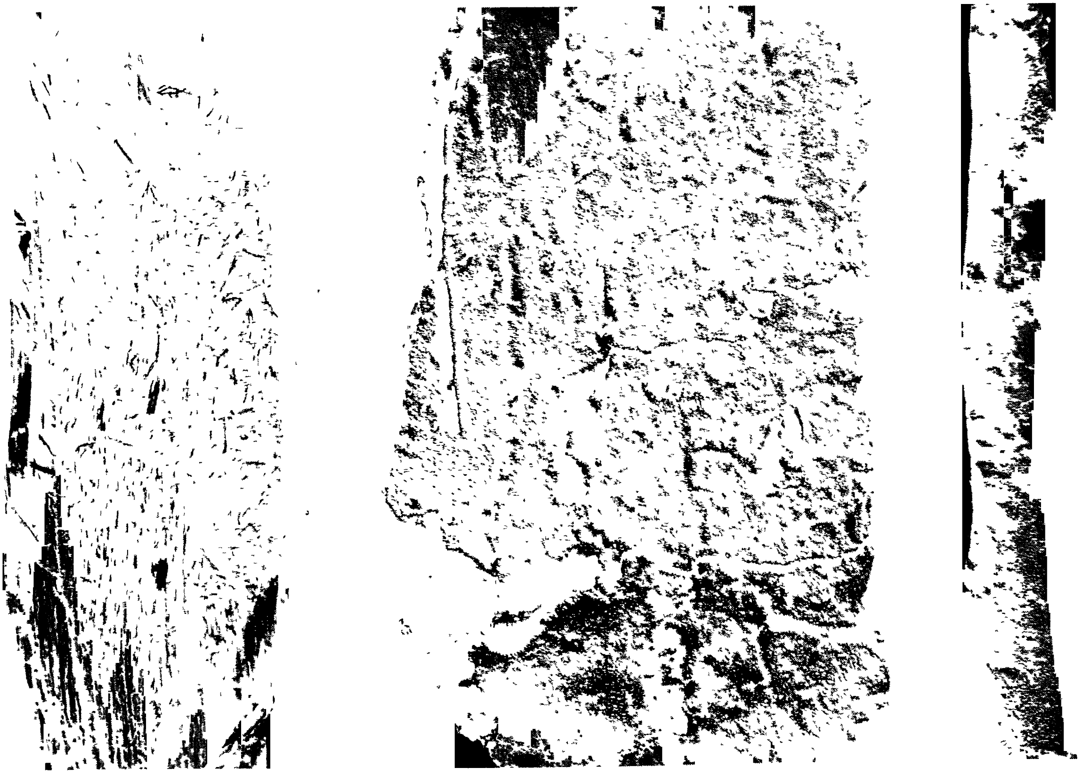
FIG. 3. *Poria aneirina* Somm., not Fr., on *Populus tremuloides*. Plant determination by L. Romell

PLATE XIX

FIG. 1. *Poria papyracea* (Schw.) Cooke on white cedar. Mackinac Island, Michigan

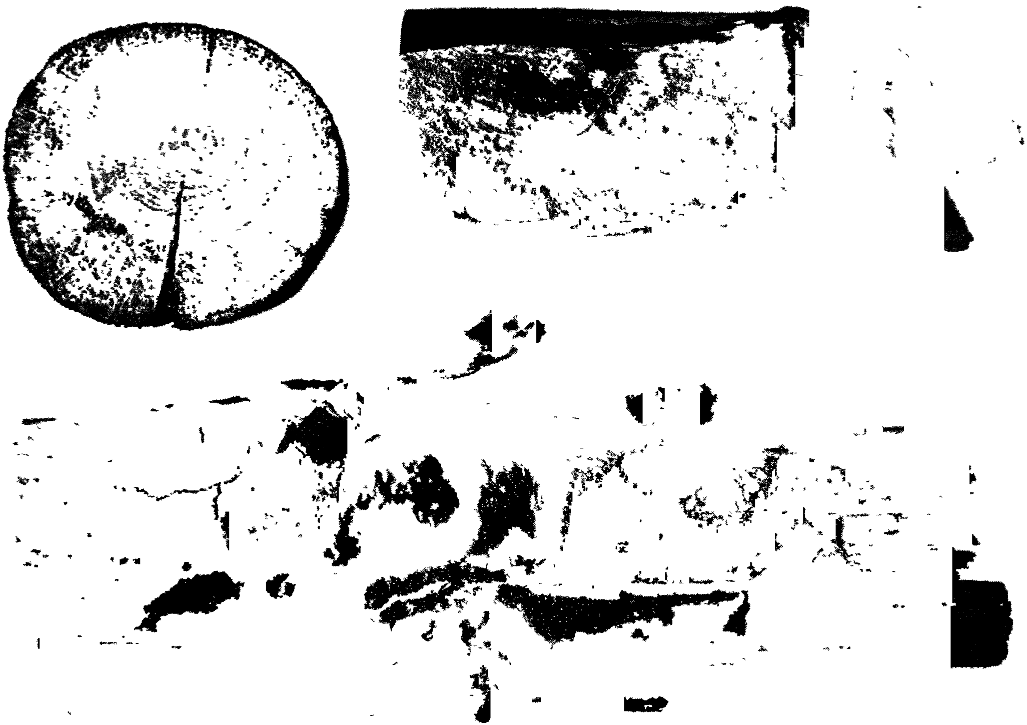
FIG. 2. *Poria eupora* (Karst.) Cooke (*Poria attenuata* (Pk.) Cooke) on aspen, Ann Arbor, Michigan

PLATE XX



Poria xantha Lind. *sensu* Romell. This plant was determined by Romell, who states that it is "identical with the vitellinus variety of *Poria xantha*." The specimen illustrated here was collected on Port Orford cedar, Port Orford, Oregon

PLATE XX



Poria semitincta (Pk.) Cooke on white oak. Ann Arbor, Michigan

PLATE XXII

Poria lenis Karst. on white pine log. Dorset, Ontario

PLATE XXIII

Poria vaporaria Fr. *sensu* Burt. This fungus was obtained from Dr. J. T. Barrett, University of California

PLATE XXIV

Fig. 1. *Poria rufa* Schr. on spruce log. Hidden Lake, Tobin Harbor, Isle Royale, Michigan

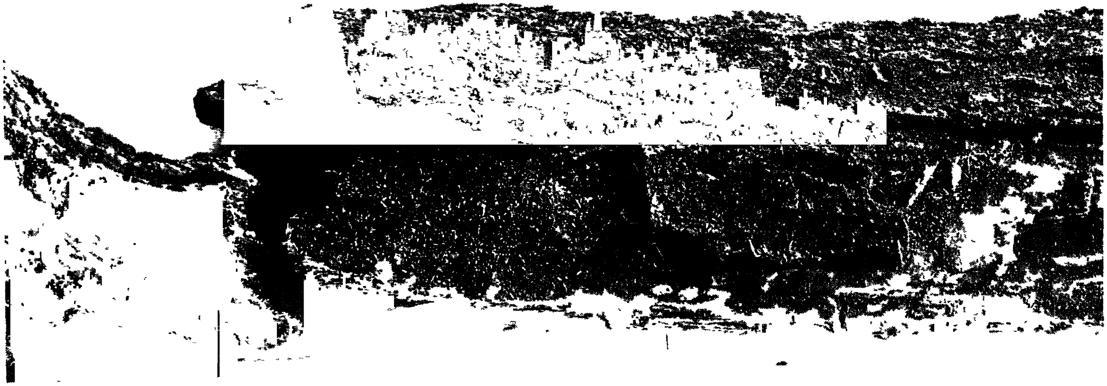


Fig. 2. *Poria spissa* (Schw.) Cooke on *Gleditsia tricanthos*, Hillsboro, Illinois

PLATE XXV

Poria subincarnata (Pk.) Murr. on spruce. Atlanta, Michigan

PLATE XXVI

Poria xantholoma (Schw.) This plant, according to Romell, is probably allied to *P. onusta* Karst., but not identical with it. *P. bombycina* is also allied to it. This particular specimen was collected on the Kaibab National Forest, Arizona

SAMPLING FOREST TYPES

SUGGESTIONS BASED ON THE MICHIGAN LAND ECONOMIC SURVEY

JOSEPH KITTREDGE, Jr., AND GEORGE T. OLSON

ADEQUATE statistics of areas of forest cover are fundamental for forestry development, on both the biological and economic sides. At the present time they are particularly needed for states or regions, in order to evaluate the economic situation and to formulate forest policies intelligently. The present Land Economic Survey in Michigan is providing these statistics by counties, in addition to much other detailed and useful information. Although a survey in this detail covers ground rather slowly, the Michigan survey has been under way so long that a large area has been mapped and the completion of the northern part of the state may be anticipated in a not distant future. For some purposes, however, it would be desirable, even in Michigan, to have the statistics of area for the whole state more promptly than they can be obtained in the present detail. The economic surveys in Wisconsin and Minnesota have started only recently, and under the same detailed plan of procedure there may be some doubt as to the availability of satisfactory state-wide statistics in any reasonable time.

The forest survey project of the United States Forest Service aims at complete statistics of areas of different categories of forest land for the country as a whole and for the different states and regions within ten years. The appropriations which have been authorized for this national survey are the equivalent of a little over one half of a cent an acre for the whole area to be covered. If one half of that amount is used for the field work, and there remain thirty-five million acres of forest land in Michigan, Minnesota and Wisconsin to be surveyed, it will not be possible to cover the area in the detailed and intensive way which has been adopted by the state economic surveys. With the appropriations available, therefore, it becomes necessary to devise some scheme of sampling the whole thirty-five million acres without attempting to cover them completely or prepare maps of the actual locations of the different classes of forest cover. If a system of line surveys were adopted, the funds available would provide for lines three miles apart, or twice through a township. The important question then naturally arises, How reliable will the statistics of areas be which may be obtained from lines three miles apart, or how many survey lines are needed to obtain any desired degree of accuracy in the statistics?

The maps of the Michigan Land Economic Survey offer excellent material for the study of the reliability of statistics derived from different intensities of line surveys. The maps of Alpena, Antrim, Ogemaw and Roscommon counties, including about sixty-eight townships, have been used as the basis for the following analysis. It is assumed that the areas of different kinds of cover, as mapped from lines one-half mile apart, with offsets as necessary, are correct. On these maps lines were laid out east and west across the central line of each tier of townships and two additional lines parallel to the center line and one and one-half miles north and south of it. The distance within each forest type in each six miles of line was measured on the maps, thus providing a total of 204 six-mile samples. For the exterior townships in each county, the areas, and from them the percentages of different forest types within each soil type, were also determined. The acreage tallies by townships made from the maps by the Survey provide a third method of sampling by township units.

Different combinations in number and arrangement of these line and township samples make possible an estimate of the reliability of the area statistics, which may be obtained by different intensities and at different costs per unit area. Starting with the two lines per township spaced three miles apart, one gets 136 samples of six miles of line, each with from zero to sixty tenths of miles of one or more forest types. On this basis the standard deviations[1] for each type were calculated.

The interest in this material concerns, not primarily the results of sampling in these four counties, but rather a prediction of the reliability of the results in a much larger area where some form of survey is in prospect. In order to apply the conclusions from these four counties to the larger area the assumption is necessarily made that the variation of types in that larger area will not be radically different from that in the four counties. Then, for this larger area, there would be a new average amount of line within each type and if we think of several larger areas of different sizes or of different samples from the whole region, of which the average for the four counties is one, then these averages would vary systematically about their mean. The averages in each case would be the number of tenths of mile of a given forest type in six-mile-line samples. The accuracy of the mean of the larger area may be evaluated from the standard deviation previously mentioned and the number of samples. This measure, called the standard error,[2] expresses the range above and below the mean of the four counties within which the mean of the larger area would fall with chances of 2 in 3. If this standard error is expressed as a percentage of the mean for each type, the accuracy within which the mean will fall two out of three times for each type is shown in column one of Table I. From these percentage standard error figures, with a minimum of ± 5 per cent for poplar and birch and a maximum of ± 62 per cent for white pine, it is evident that the reliability of the line survey would be satisfactory for the more abundant types and unsatisfactory for the uncommon types,

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[1] SD equals $\sqrt{\frac{\Sigma(X)^2 - M^2}{N}}$, when SD equals standard deviation, X equals value of one sample, N equals number of samples, and M equals the mean of the samples or $\frac{\Sigma X}{N}$.

[2] SE equals $\frac{SD}{\sqrt{N-1}}$, when SE equals standard error, SD equals standard deviation, and N equals number of samples.

TABLE I

RELIABILITY OF STATISTICS OF AREA OBTAINED BY LINE SURVEY AND OTHER METHODS

Forest types	1	2	3	4	5	6	7
	Two strip-lines per twp.			Three lines per twp. Chances 19 in 20 No. of samples required	Percentages of forest types in Ogemaw County from		
	Chances 2 in 3 SE in percentage	Chances 19 in 20			Acreage tally	Roscommon County percentages	
		No. of samples required	No. of twps.			Directly	By soil types
Poplar and birch..	5	277	138	270	41.1	31.7	41.9
Hardwood-hemlock	13	928	464	985	3.5	0.3	3.3
Elm-ash..........	16	1417	708	1317	4.1	6 5	8.2
Cedar............	18	1806	903	1730	7.8	14.6	7.0
Oak.............	20	2209	1104	2209	25.5	29.5	24.7
Marsh and bog....	21	2341	1170	2160	......	.....	.....
Spruce...........	26	3600	1800	3647	0.4	0.3	2.2
Jack pine.........	31	5041	2520	4764	11.2	6.4	6.2
Open wild land....	38	7887	3943	8898	6.3	9.9	5.2
Tamarack........	47	12499	6249	12769	......	.....	.....
Norway pine......	48	12769	6384	11025	0.08	0.5	0.8
White pine.......	62	24964	12482	26896	0.04	0.3	0.5
					100.02	100.0	100.0

like white and Norway pine. The large standard errors for the pine types are undoubtedly due to the small amount and erratic distribution of the samples of those types. So far, the conclusion might be drawn that a line survey of two strip-lines per township would give reasonably reliable figures of area for the abundant types, like poplar and hardwood, but not for the infrequent types, like white and Norway pine.

For most purposes statistics of forest areas for states or regions are sufficiently accurate, if they are within 10 per cent of the truth. If, then, 10 per cent is set up as the desired degree of accuracy and it is assumed, as before, that the larger areas, whole states or regions, will have about the same variability in forest types as the four counties, the number of samples may be calculated which would be required to provide results accurate within 10 per cent for specified chances or probabilities. It is probably desirable to be more certain of obtaining the 10 per cent accuracy than would be indicated by one standard error or chances of 2 in 3. Twice the standard error represents chances of 19 in 20 that the mean of the four counties will be within that range of the true mean. In this way the number of samples required for each type, in order that its area might be predicted within 10 per cent of the true value with chances of 19 in 20, was computed[3] and is shown in column 2 of Table I. The third column gives the number of townships which would have to be covered in order to obtain this number of samples and the 10 per cent reliability for each type. The smallest number of samples, or of townships, is needed for the abundant types, like poplar and hardwood, and the largest number for the infrequent types, like Norway and white pine. There are about 300 townships in the northern part of the Lower Peninsula of Michigan. This would be sufficient only to provide enough samples for an estimate of areas reliable within 10 per cent for the poplar and possibly the hardwood types. There are approximately 1,700 townships in the 35,000,000 acres to be covered in the region. On this much larger area two strip-lines per township would provide statistics of the same degree of accuracy for all the types except spruce, jack pine, open wild land, tamarack, Norway and white pine. If the types were combined into groups, as they might be for many purposes, the statistics would be sufficiently reliable for these groups with the possible exception of the pine group.

For comparison, similar calculations have been made for line surveys of three and one strip-lines per township, having totals of 204 and 68 samples, respectively, instead of 136, as for the two lines per township. For poplar the 10 per cent accuracy would be obtained from 270 and 254 samples, in comparison with the 277 samples necessary for the two lines per township. The values for the other types for three strip-lines per township are also shown. It will at once be noted that, for any one type, the necessary number of samples, and also the reliability of results from such samples, whether one, two or three miles apart, are essentially the same. The conclusion is obvious that after obtaining as many as 136 samples, and probably somewhat less than that, the reliability of the statistics of area no longer increases as the number of lines per township is increased, but is dependent wholly upon the variability of the distribution of a given type within the samples. Therefore, so far as the dispersion within the samples of a type is concerned, increasing the number of line samples beyond a certain point, or decreasing the spacing between the lines, will not increase the accuracy of the resulting figures of area. Combining the six-mile into twelve-mile samples does not change the conclusions significantly.

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[3] N_r equals $\left(\frac{SD}{SE}\right)^2$ plus 1, where N_r equals the required number of samples. Since the condition is set that 2 SE equals 0.1 M, this becomes, N_r equals $\left(\frac{SD \times 2}{0.1\,M}\right)^2$ plus 1.

Another method of sampling would be to survey certain townships with strips one-half mile apart, as is now done in the Michigan survey, and limit the number of townships surveyed to those needed in order to insure statistics accurate within 10 per cent when the figures from the sample townships are applied to a larger area. By this method the number of townships required would be 204 for poplar and 3,648 for Norway pine, with intermediate values for the other types. These numbers of townships, with 12 strips through each township, would require for poplar 2,448 six-mile strips, as compared with the 277 needed by the method of 2 six-mile-line samples in every township. The conclusion is evident that the line sampling is far more reliable for the same expenditure of time and money than is the method of township sampling.

The reliability of estimates of areas of forest types, whether by lines or townships, may be increased by the use of forest type–soil type relations where soil surveys are available. This was tested by using the Roscommon County percentages, first, of forest types, and, secondly, of forest types on each soil type, to predict the areas of forest types in Ogemaw County. The percentages based on areas by the two methods and the actual acreage tally are shown in Table I, columns 5, 6 and 7. The percentages by soil types are closer to the actual in all the important types except elm and jack pine. The standard error of the prediction directly by forest types is ± 45 per cent and by soil types is reduced to ± 22 per cent of the mean.

Another and apparently independent source of error in sampling lies in the fact that the lines will not cross the types exactly in proportion to their areas. Obviously, a line may cross a narrow neck of swamp which widens out on both sides, but does not extend as far as the next line on either side. In surveys of large areas this error is reduced because the individual errors tend to compensate one another. This source of error is directly a function of the spacing between lines and is reduced as the lines are spaced closer together. Evidently, if the lines were very close together, there would be a negligible error because the whole area would be covered, but in lines two or three miles apart this is not true. The same material from the Michigan survey was used to test the magnitude of this error for different numbers of lines per township. The distances in each type along the strip-lines were totaled and the percentages which the totals for each type formed of the grand total for the four counties were applied to the total land area of the four counties to obtain a prediction of the area of the different forest types. These predicted areas are compared with the actual areas obtained from the maps in Table II for lines 2, 3 and 6 miles apart. The differences within many of the types, whether expressed in acres or as percentages, are large. If the differences for all the types are combined in a figure analogous to the standard error, the comparison between the three intensities of survey shows that, with chances of 2 in 3, one strip per township will be wrong by not more than 73 per cent, two strips per township by not more than 38 per cent, and three strips per township by not more than 27 per cent of the average area of the fourteen types. This source of error apparently does not depend upon the abundance of a type,

TABLE II

Comparison of Actual and Predicted Areas of Forest Types for Lines 2, 3 and 6 Miles Apart

Forest type	Actual	Predicted from strips per township (Areas in 1000 acres) 1	2	3
Poplar and birch	386.6	188.2	404.6	404.4
Hardwood-hemlock	145.2	172.5	218.0	182.2
Elm-ash	70.9	109.8	87.8	83.5
Cedar	113.3	94.1	78.4	74.9
Oak	173.9	141.1	106.6	102.2
Marsh and bog	46.8	78.4	51.7	52.8
Spruce	2.9	47.0	42.3	39.0
Jack pine	54.8	78.4	53.3	54.4
Open wild land	14.5	47.0	37.6	34.3
Tamarack	6.3	3.1	3.1	2.8
Norway pine	4.5	7.8	3.1	3.5
White pine	2.1	1.6	1.6	1.4
Cleared land	336.0	517.5	370.1	367.9
Water and towns	210.2	94.1	109.8	164.5

since it is decidedly higher for poplar and birch, the most abundant type, than it is for spruce or hardwood or open wild land, which are distinctly less common types. A comparison of the standard error by two lines per township in the four counties, 39 per cent, with that derived from only two counties, 57 per cent, indicates that this error also decreases as the total area surveyed is increased.

It was shown in the foregoing discussion that a line survey of two or three lines to the township would not furnish very reliable statistics of area of the uncommon types. The most important thing from the economic standpoint is to know the area of the important groups of types rather than of the rare types. If the types are combined into six and the areas predicted from the line survey twice through a township for these six types, the standard error expressed as a percentage of the mean becomes 20 per cent instead of the 39 per cent obtained in the previous calculation.

In conclusion, if it is permissible to judge the probable reliability of statistics of forest areas derived from line or other kinds of surveys for states or regions from a sample of only four counties, the foregoing analysis leads to the following summary:

The accuracy of areas, so far as the variability of the type within the samples is concerned, depends upon the total number of samples obtained in the whole area surveyed and not upon their spacing. One hundred samples may be sufficient to give 10 per cent accuracy 19 out of 20 times with poplar, an abundant type, whereas over 6,000 would be needed to give an equally reliable figure for Norway pine. Two lines per township would give this degree of reliability for a majority of the types or for groups of types in a survey of the whole Lake States region.

Line samples provide more reliable figures for the same expenditure of time and money than do township samples.

The reliability of areas of forest types may be greatly increased by applying their distributions by soil types to the soil type areas where soil surveys are available.

The errors due to the fact that the proportions of types along strip-lines do not correspond to the actual proportions of area are high in these four counties. This error is reduced in almost direct proportion as the number of strips per township is increased.

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THEORY AND PRACTICE OF FOREST TYPING, WITH SPECIAL RELATION TO THE HARDWOOD AND HEMLOCK ASSOCIATIONS OF NORTHERN MICHIGAN

GEORGE S. McINTIRE

A FOREST type, according to a committee of the Society of American Foresters on forest terminology,[1] is "a descriptive term used to group stands of similar character as regards composition and development due to given physical and biological factors, by which they may be differentiated from other groups of stands. The term suggests repetition of the same character under the same circumstances."

That foresters are not in agreement in their field interpretation of "type" is evidenced by the many and varied representations given to some of the forest associations in the Lake States. This is responsible for some confusion and has increased the number of types in that many widely varying transitory combinations are recognized as such.

Forest cover is classified on the basis of forest types. It is, therefore, imperative that the type classification of a given physiographic region be the medium by which the character of any stand within that region is portrayed. Political or economic conditions may influence to a considerable degree the intent in ownership and consequently the utilization planned for a particular stand. In such a case the mapping of a forest area on the basis of future utilization rather than on the basis of the actual composition existing on the ground may be perfectly justified. But the results of such a procedure do not fulfill the specifications of a type map and should not be regarded as such.

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[1] "Committee Report — Forest Terminology," *Journ. Forestry,* 15 (1917): 80.

Moreover, we should not lose sight of the fact that type mapping on any basis other than that of actual occurrence requires the exercise of a field judgment which spans at least two complete phases of research, the economic and the silvicultural. For example, a good deal is taken for granted when a stand of 20 per cent Norway pine and 80 per cent aspen and white birch is mapped as a Norway pine type merely because that species will produce the best saw log. An interpretation of such a stand as it actually occurs on the ground will be of more value for any conceivable purpose of utilization than one which tells only part of the story. Offhand, it would seem that elimination of the so-called lesser important components of a combination stand would simplify the task of the field man. But it has been repeatedly illustrated by the Michigan Land Economic Survey field crew that the men work faster and more accurately and that their maps correlate more closely if they are given the single criterion of physical occurrence on which to base their interpretations.

The virgin associations of northern Michigan were definite in character and comparatively simple in composition. Second-growth stands which have been only cut over retain many of the characteristics of the original forest and in general represent a comparatively simple problem in forest typing. The more intricate problem occurs on those marginal areas in which the original forest was made up of a combination of two or more types, and which have been both logged and burned over. Typical examples of such conditions occupy those transitory situations which once supported a mixture of the maple–yellow birch, the hemlock and the swamp conifer types, and upon which such species as aspen and fire cherry further complicate the problem of forest typing at the present time. A condition even more typical is that offered by a mixture of white pine, aspen, white birch, white cedar, spruce and balsam fir, which represents in varying degrees the white pine type, the aspen type, the white birch type and the swamp conifer type.

It is true that on such situations 70 or 80 per cent of the stand is often made up of representations of two basic associations, and it would rightly be considered splitting hairs to symbolize on the map every type that is on the ground. It does not follow, however, merely because a type does not occur in sufficient strength to be recognized in the typing that it may not greatly increase the complexity of the problem. And unless the field mapper is supplied with a classification of the basic associations of the region it is impossible for him to decipher the situation correctly. If this classification is lacking, perhaps his first inclination will be to make a new type to describe this particular condition. Or he may become confused and start guessing, which is always disastrous. In either case, he will be unable to interpret the situation correctly. His type lines may be placed at right angles to their correct position; his type separations will be made in faulty locations, and his confusion will continue even after the complicated condition evolves into the more simple associations. A hazy and erroneous interpretation of the area is the usual result. This is exactly what happened in a certain instance in northern Michigan when the boundary of a well-defined coniferous swamp type was made to swing up a fifteen-foot escarpment to include an area which supported a few suppressed balsam firs under a high forest of virgin upland hardwoods. The type separation should rightly have been located at the base of the escarpment, where the more marked change in composition occurred.

A common fault in type mapping is the tendency to place too much emphasis on the area under treatment in the construction of the type classification. A correct type map cannot be made of any given tract without first considering associations on the entire physiographic unit in which it occurs. It is, therefore, impossible to construct a type classification of any local area without a comprehensive knowledge of the basic associations of the region. A procedure to the contrary may fulfill the requirements of the owner of a particular tract, but its results may have but little correlation with the stands of the surrounding area. Certain slight local variations of a type peculiar to a very limited condition may be interpreted as typical rather than as an exception. Often there are several local variations and if an intimate knowledge of the more typical basic association is lacking, confusion will undoubtedly result. It does not necessarily follow that such local variations may not deserve recognition by some method on those particular areas on which they occur. But it is more direct and logical to work from a basic association toward its variations, for only in such a manner can the relative degree and extent of the variations be determined. The forester has certain definite criteria for the purpose of determining stocking. He would consider it illogical to call a stand of any given type well stocked merely because it represented the maximum degree of stocking attained by that particular type within the area under treatment. But it would be no less incorrect to type a given area without using the basic associations of the region as the criterion for the grouping of species into types. In order, therefore, to portray the true character of the various compositions it is essential that a measuring stick be used which is applicable to the entire physiographic region.

A general reconnaissance will always be of value for certain purposes, but the time is past when such an interpretation is of much significance in application to any definite project. The Land Economic Survey was made to realize this fact early in its history when the knowledge was forced upon it that the small individual landowner represented the largest class of map users, and that John Jones, who owned two "forties" in Ogemaw County, was far more interested in what was on his own land than he was in the total number of acres of aspen or jack pine within the county. It soon became evident that the state, as the largest single user of the maps, was more directly concerned in an accurate and precise portrayal of each "forty" in which it has an interest than in a generalized summary of any particular county or township.

In mapping fourteen counties of northern Michigan the Land Economic Survey has demanded that an association of forest species possess additional qualifications before it can be recognized as a type. It has been the experience of the Survey that there are certain definite situations which, because of their constant and stable character, must be recognized as the basic units; and that when the influence of two or more such conditions is brought to bear on the same area, the resulting combination is an indefinite thing which varies in composition with the relative strength of these various influences on that particular area. The Survey has held that such a composition, regardless of how common may be its occurrence, should not, because of its variable and unstable character, be recognized as a type or basic unit.

During the working of Chippewa County in 1926 a swamp conifer type (mainly black spruce) and an aspen type were recognized by the Survey in the mapping. The two species occurred together over large areas, and despite the fact that this situation was much more common than some of the more stable associations it was recognized, not as a type, but as a combination of two types, the more prevalent being designated by the arrangement of the symbols. But even this was inadequate. The representative of a Canadian pulp concern interested only in spruce inspected the survey maps in search of merchantable spruce stands. On spruce-aspen areas where our symbolization showed spruce as being the more prevalent, we were unable to tell him whether 51 or 90 per cent of the stand was spruce. In aspen-spruce stands where aspen was shown to be the more prevalent we were unable to tell him whether 10 or 49 per cent of the stand was spruce. The Survey maps at that early date did not convey as much information as they do at the present time, but certainly they were much more valuable to him than if we had recognized the spruce-aspen combination as a single type.

This case only serves to illustrate that a type classification can have practical value only so long as the types are held to interpret those associations of constant and definite character. So far as we know, the spruce-aspen combination is not generally recognized as a type. But what, for instance, of the so-called hardwood-hemlock type, the beech–hard maple–hemlock type or the hard maple–yellow birch–hemlock type? Hemlock occurs in pure stands on physiographic situations which may differ considerably from those occupied by the hardwoods. Typical examples of such stands are located on Section 16, T. 48 N., R. 16 W., in Alger County and on Sections 25, 26 and 36, T. 45 N., R. 8 W. in Luce County. The maple–yellow birch type, which is often associated with widely varying amounts of hemlock, also occurs to the absolute exclusion of that species. It is hardly conceivable that a statement to the effect that neither of these should be considered as a hardwood-hemlock type would be disputed. This is obviously inconsistent with the definition of a forest type. But the hardwood-hemlock combinations vary from 90 per cent hardwood, 10 per cent hemlock to 90 per cent hemlock, 10 per cent hardwood, and it is just as inconsistent to combine the two as a single type on transitory situations that vary so widely.

The Land Economic Survey attempted to use a hard maple–yellow birch–hemlock type in the working of Alger County. It failed to fulfill the one test of a type classification in that it did not work out on the ground. Because of its widely varying composition we were continually changing our interpretation of it and finally discontinued its use entirely. The most that can be done in the description of such a combination is to admit that it can have only a general application. A hardwood-hemlock type can have little definite meaning on the map, whereas to the man in the field it can mean only that the person responsible for the type classification either had in mind merely a very general reconnaissance or was unfamiliar with actual field conditions. Neither interpretation will tend to elevate the quality of his field work.

The accompanying table (Table I) of sample plots taken in various counties mapped by the Survey illustrates the wide range in composition which occurs in the hardwood-hemlock combinations.

Another cause of vagueness and misinterpretation in forest typing occurs within the upland hardwood compositions. It has been said by one high in the forestry profession that the term "northern hardwoods" as a type name has been considered justified because of its long, wide and consistent use. This term certainly has been long and widely used, but the most consistent thing about it has been the indefiniteness and inconsistency of its application. It has been applied in various instances to each of the more extensive upland hardwood associations of northern

TABLE I

SAMPLE PLOTS TAKEN IN VIRGIN STANDS, SHOWING THE VARIATIONS IN THE AMOUNT OF HEMLOCK OCCURRING IN ASSOCIATION WITH THE UPLAND HARDWOOD SPECIES

Plot no.	County	Basal area per acre						
		Hemlock		Upland hardwoods *		Other species †		Total
		Sq. ft.	Percentage	Sq. ft.	Percentage	Sq. ft.	Percentage	
31	Alger	1.9	1.4	134.0	98.3	0.4	0.3	136.3
13	Kalkaska	2.5	1.8	130.3	97.8	5.0	0.4	137.8
21	Alger	2.7	1.7	141.2	91.1	11.2	7.2	155.1
40	Luce	3.5	3.1	105.6	92.8	4.7	4.1	113.8
15	Kalkaska	5.3	12.8	36.2	87.2	....	...	41.5
24	Alger	7.3	5.6	114 9	88.0	8.4	6.4	130.6
17	Alger	9.5	14.0	57.7	84.2	1.2	1.8	68.4
7	Menominee	12.8	9.3	114.1	90.0	10.1	0.7	137.0
32	Luce	15.1	11.4	109.8	83.9	7.7	4.7	132.6
18	Luce	29.2	22.8	87.5	68.4	11.1	8.8	127.8
27	Kalkaska	95.1	57.8	68.8	42.2	....	...	163.9
17	Menominee	116.8	64.3	57.6	29.9	7.9	5.8	182.3
3	Menominee	116.8	63.9	66.6	36.1	....	...	183.4
4	Menominee	174 8	72.3	66.8	27.7	....	...	241.6
8	Alger	188.6	58.2	131.8	41.8	....	...	320.6
11	Chippewa	194.6	63.9	90.8	29.6	20.0	6.5	305.4

* Upland hardwoods = hard maple, beech, elm, basswood, yellow birch

† "Other species" may include such occasional individuals as balsam fir, white pine, black cherry, mountain ash, ironwood and red maple.

Michigan. In other places it has been used as a blanket to cover any upland hardwood situation. It is a convenient term, but it means little unless accompanied by an explicit description, which has often not only been lacking but also, seemingly, avoided. It is nothing more definite than the broad generalization of a group of conditions. Covering as it does a wide variation in site as

TABLE II

BASAL AREA OF SAMPLE PLOTS TAKEN IN VIRGIN AND CUT-OVER STANDS, SHOWING THE CHARACTERISTIC COMPOSITION OF THE MAPLE-BEECH TYPE

County	Plot no.	Virgin or cut-over	Basal area per acre by species			
			Hard maple	Beech	Yellow birch	Other species *
			Sq. ft.	Sq. ft.	Sq. ft.	Sq. ft.
Alger . . .	34	cut-over	65.6	32.3	6.2	5.0
Do.	56	do.	29.4	22.6	5.8	16.3
Do.	37	do.	10.8	30.4	12.1	6.1
Do.	31	do.	58.9	68.9	6.3	2.2
Do.	10	do.	40.8	34.3	47.3	14.7
Do.	49	virgin	81.3	19.8	7.4	1.2
Do.	50	do.	37.7	60.8	29.3	7.5
Do.	51	do.	36.4	9.0	2.1	3 6
Luce. . . .	6	do.	94.8	8.0	11.1	6.9
Do.	36	do.	9.1	17.0	4.0	8.2
Do.	40	do.	35.2	35.7	21.9	18.1
Chippewa	5	do.	38.2	10.1	14.2	1.8
Do.	6	do.	41.7	17.9	2.9	0.1

* "Other species" may include cherry, red maple, white pine, hemlock, ironwood and mountain ash.

well as composition, it is no more justified as a type name than the grouping of jack, Norway and white pine into a single pine type.

The Land Economic Survey has recognized in Upper Michigan four distinct upland hardwood types, which are as follows:

M = hard maple, beech, elm, basswood, yellow birch;
Mb = hard maple, beech, yellow birch;
Me = hard maple, elm, basswood, yellow birch;
My = hard maple, yellow birch.

The species are arranged in the order of their usual occurrence in the stand. Hard maple and yellow birch are present throughout all four types, with maple ranking first in abundance and

TABLE III

BASAL AREA OF SAMPLE PLOTS TAKEN IN VIRGIN AND CUT-OVER STANDS, SHOWING THE CHARACTERISTIC COMPOSITION OF THE MAPLE-ELM-BASSWOOD TYPE

County	Plot no.	Mature or cut-over	Basal area per acre by species				
			Hard maple	Elm	Bass-wood	Yellow birch	Other species*
			Sq. ft.	Sq. ft.	Sq. ft.	Sq. ft.	Sq. ft.
Alger	16	cut-over	40.6	40.0	4.0	3.2	...
Do.	1	do.	62.4	23.0	61.0	9.5	5.7
Do.	20	do.	75.8	24.0	2 0	1.5	2.0
Do.	25	do.	55.8	22.0	5.4	2.9	...
Do.	14	virgin	103.0	36.0	13.5	2.28	...
Do.	4	do.	100.1	34.2	28.9	8.0	2.7
Do.	13	do.	111.8	9.6	13.5	4.3	3.3

* "Other species" may include balsam, poplar, white pine, hemlock and ironwood.

yellow birch usually ranking last. Beech, elm and basswood are the indicators, and it is the presence or absence of one or more of these species which gives character to the association.

As regards composition, rate of growth, volume and character of the site occupied, the maple-beech type and the maple-elm-basswood type represent the two most widely contrasting associations of the upland hardwoods.

Tables II and III, showing basal area by species of sample plots taken in typical stands of these two types, illustrate the consistency of composition within each type as well as the contrast between them.

Although the two types often occur closely related geographically there are vast areas where one may occur to the absolute exclusion of the other. To illustrate, the maple-beech type does not exist on a single acre of thousands of acres of hardwood land in Iron County. With the exception of the areas which are occupied by the maple–yellow birch type the entire upland hardwood acreage is composed of the maple-elm-basswood–yellow birch association. The writer has spent two field seasons in Iron County and has never seen a beech tree within its boundaries. On the other hand, in northeastern Alger County, on an area of approximately six and one-half townships extending eastward from Beaver Lake in T. 48 N., R. 16 W., to the Luce County boundary, the Land Economic Survey maps show more than 100,000 acres of the maple-beech type and only two small patches of the maple-elm-basswood type, with a total area of less than 100 acres.

With regard to these two conditions the following facts are worthy of note. The maple-elm-basswood type occurs in southwestern Alger County and in Iron County on the heavier soils such as Trenary loam, Trenary sandy loam and Iron River loam and silt loam. On the other hand, the maple-beech type in northeastern Alger County is confined to the lighter, more sandy, soils, such as Strong's loamy sand, Luce loamy sand and Au Train sand. G. I. Stewart, in his growth studies conducted in Alger County for the Land Economic Survey, found, on the basis of measurements of more than 600 trees, that hard maple on Trenary loam made a height growth of 65.5 feet in one hundred years, whereas that species on Luce sand in a similar period attained a height of only 46 feet. Mill-run figures, were they available, would undoubtedly show an even greater contrast between the two types, since the trees of the maple-elm-basswood stands are taller, straighter, larger in diameter, and carry a much smaller proportion of cull and defect than do those of the maple-beech stands.

Tables IV and V of sample plots of the two types, taken on soils on which they represent the typical virgin growth, show a considerable difference in the basal areas attained by the respective types on these soils.

Because of such definite and constant associations existing within the broad upland hardwood forest, together with the wide range of conditions represented, it at once becomes evident that volume and growth-rate figures based on data taken promiscuously

TABLE IV

Sample Plots Taken in the Maple-Beech Type, Showing Basal Area and Cubic Volume per Acre

County	Plot no.	Soil type	No. of trees *	Basal area
Alger	50	Kalkaska sand	288	135.51
Do.	49	Kalkaska sand	516	109.57
Do.	43	Luce sand	224	122.17
Luce	39	Au Train sand	258	118.29
Do.	40	do.	310	113.9
Average per acre			319	119.9

* "Number of trees" includes all stems over 0.5 inch D. B. H.

TABLE V

Sample Plots Taken in the Maple-Elm-Basswood Type, Showing Basal Area and Cubic Volume per Acre

County	Plot no.	Soil type	No. of trees *	Basal area
Alger	2	Trenary loam	672	227.9
Do.	4	do.	384	216 96
Do.	13	do.	556	143.44
Do.	14	do.	1930	145.9
Do.	15	Chatham loam	672	120.1
Do.	30	Onota loam	584	212.36
Average per acre			799	177.8

* "Number of trees" includes all stems over 0.5 inch D. B. H.

without regard to soil, site or variation in composition cannot be applicable to any particular hardwood stand. It is further evident that data representing conditions on one phase of the upland hardwoods cannot be applied to other phases which represent such radical differences in both site and composition.

According to the accepted definition, the term "type" should "suggest repetition of the same character under the same circumstances.'' Therefore, the grouping of so widely varying associations under the head of a single forest type does not conform to either the literal or practical interpretation of the definition.

It is an easy task to construct a type classification for a particular area, but the true test of such a classification is in its application, and it is not quite so simple to prepare a classification which will accurately portray the forest composition as it occurs on the ground and at the same time furnish the basis of correlation with other stands. It is always enlightening to remember, when a classification does not fit, that it is the interpretation and not the condition which is at fault. On the other hand, it is often surprising how an approach from a slightly different angle will smooth out seemingly glaring inconsistencies, and how easily a complicated situation may be interpreted after the correct perspective is attained. Because a slight distortion of basic associations may be greatly magnified in its application, thus obscuring the true character of the situation by a faulty viewpoint, we owe it to the man in the field to make his approach as direct as possible.

We have heard a great deal of late about the establishment of a correlation between soil and forest growth. The substantiation of such relationships would undoubtedly have great practical value. It is generally conceded that soil conditions exert considerable influence in determining the character of the vegetation and that certain more or less definite relations do exist in nature, but the extent to which such a correlation can be established between soil and forest types depends almost entirely upon the capacity of our type classifications to interpret the actual conditions correctly.

Forest typing on the basis of composition is being carried on in all parts of the country by many agencies with a great variety of interests. A type classification, in order to be a help rather than a hindrance in any given locality, must be basic and deal with basic associations. Furthermore, it is essential, while the types themselves are held to those associations of constant and definite character, that the type classification be capable of considerable elasticity in its application. Otherwise it cannot possibly portray the composition and character of the stand. It must furnish the medium by means of which correlation is developed beween the simple and the complex situations. Let all interests engaged in forest classification combine or juggle these basic units to suit their own particular needs. They will do this anyway. But certainly a correct type classification should furnish them with the basic associations, so that they will at least recognize the units with which they are building. Only with such an understanding can the mapper in the field intelligently place his boundaries, and only in this way will correlation in typing within and between natural districts be attained.

DEPARTMENT OF CONSERVATION
LANSING, MICHIGAN

A SHORT METHOD OF ESTIMATING POSSIBILITIES OF SUSTAINED YIELD IN FOREST PRODUCTION *

DONALD M. MATTHEWS

THE data supplied by the ordinary timber survey of any large area are generally not sufficiently detailed to permit a reasonably accurate estimate of possibilities of sustained yield. Nevertheless, the forester often has to work with such data, supplemented by such field observations as he can make during a few field inspections, and to draft a plan of management which aims at continuous production for the property. The value of any plan which he produces will be affected by his ability to recognize what data are lacking from among those which are already available and by his skill in collecting additional essential information quickly and inexpensively.

Most data on timber survey can be reassembled in form to show what essentials are lacking, thereby directing attention to them and the best method of acquiring them. Let us assume that the data already available have been arranged somewhat as indicated to be desirable by Roth[1] in his *Forest Regulation:*

Hardwood and hemlock forest of 22,500 acres.
Merchantable area 15,000 acres.
Stand average 10 M. feet per acre — total 150,000 M.

DESCRIPTION OF STANDS

"Stand Class" 1)	Old timber ("all old stands"), defective, "going back," need cutting at once	2,500 acres
" " 2)	Old timber in good condition, no middle age (size) stuff	5,000 "

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* Contribution No. 27 from the School of Forestry and Conservation, University of Michigan.

[1] Roth, Filibert, *Forest Regulation*, Second edition (Ann Arbor, Michigan, 1925), pp. 67–69.

"Stand Class"	3)	Mixed-age ("all age") stands in good condition, some net growth in vol., more in quality (or size) of trees	7,500 acres
" "	4)	Young stands with little or no merchantable stuff; good growth in vol. and quality, generally over 25 ft. in height	4,000 "
" "	5)	Young hardwood thickets, very little of young hemlock, too dense in places	1,000 "
" "	6)	Cut-over areas, cut in last five years, some burned over, very little reproduction and this poor, much pin cherry brush	2,500 "

A few hundred large white pine in old stands; and on about 500 acres there is scattering white pine reproduction in isolated clumps, doing well.

These data will ordinarily have been compiled from cruise sheets, which may or may not give details of the distribution of the merchantable stand through the diameter classes, but which will certainly indicate the lower limit of merchantability as regards diameters estimated and the average and maximum sizes of the important species.

Entirely lacking will be data on ages at various sizes and the proportionate representation and age of non-merchantable timber in the various stand classes. These data the forester will now have to acquire. His general knowledge of the region in which he is working and the species with which he has to deal should be sufficient to enable him to set approximately the average age of trees of various sizes. This estimation can be checked with reasonable accuracy for the purposes of preliminary management by a few stump counts and increment borings. In his field inspections he may most usefully concentrate his attention on the estimation of age-class distribution of the non-merchantable size classes through the merchantable portion of the stand and on estimation of the age classes included in the non-merchantable areas, their stocking, and similar things. A few strip estimates in every stand class will be necessary to check his judgment on these points, but he may rely largely on ocular estimation in collecting these data, which are to be used only for drafting a preliminary plan.

His field inspections should enable him to rewrite his data on "description of stand" in the following form:

Stand Class I — 2,500 acres (all old stands)

0–40 years	20% —	500 acres	
41–80 "	10% —	250 "	
141+ "	70% —	1,750 "	@ 14 M. per acre ±
Total		2,500 "	@ 10 M. per acre as per estimate

Stand Class II — 5,000 acres (old timber)

0–40 years	20% —	1,000 acres	
41–80 "	20% —	1,000 "	
141+ "	60% —	3,000 "	@ 16.5 M. per acre ±
Total		5,000 "	@ 10 M. per acre as per estimate

Stand Class III — 7,500 acres (mixed age)

0–40 years	20% —	1,500 acres	
41–80 "	20% —	1,500 "	
81–120 "	10% —	750 "	
141+ "	50% —	3,750 "	@ 20 M. per acre ±
Total		7,500 "	@ 10 M. per acre as per estimate

Stand Class IV — 4,000 acres (young stands)

0–40 years	30% —	1,200 acres
41–80 "	70% —	2,800 "
Total		4,000 "

Stand Class V — 1,000 acres (hardwood thickets)

0–40 years 100% — 1,000 acres

Stand Class VI

For practical purposes not now reproducing on account of fire; therefore, age class 0.

With this set of descriptions in hand a tabular statement of data on age and stand can be prepared as illustrated on page 256.

This tabulation indicates that 37.8 per cent of the total area of 22,500 acres, or 8,500 acres, carry mature timber now ready for cutting and that the lower age classes are represented in accordance with their percentage figures. Expressed in terms of a 160-year rotation, this means that 61 acres out of every 160 carry timber ready for cutting, and in terms of a 120-year rotation, 45 acres out of every 120 carry mature timber. When this tabu-

AGE-CLASS DISTRIBUTION FOR TOTAL AREA AND FOR REPRESENTATIVE ROTATIONAL AREAS

Age class	Effective area in acres	Percentage	Acres in rotational 160-year area	Acres in rotational 120-year area	Total merchantable volume	Merchantable volume per acre of effective area
0	2,500	11.1	18+	13+		
0–40	5,200	23.1	37	28−		
41–80	5,550	24.7	39+	30−		
81–120	750	3.3	5+	4−		
141+	8,500	37.8	61−	45−	150,000 M.	17,650 ft.
	22,500	100%	160	120		

lation is expressed diagrammatically, the approximation of present conditions to the normal distribution of age classes becomes apparent.

The diagram (Fig. 3) illustrates the proportionate distribution of age classes for a rotation of 160 years. The line *A–B* may be referred to as the "potential production line." Points *a*, *b*, *c*, *d*, *e* and *f* are read from it. That is to say, point *a*, which indicates the lower limit of the 0–40 age class, is read from the ordinate 0 on the potential production line. Point *b*, the upper limit of the 0–40 age class, is read from the point where the 40-year ordinate crosses the potential production line. If age class distribution were normal, all points from *a* to *e* would lie on the potential production line at the point where their respective age ordinates crossed it. To the extent that age-class distribution is abnormal, these points lie above or below the potential production line. In this case points *a*, *b* and *c*, representing respectively 0, 40 and 80-year timber, lie below the line. Points *d* and *e*, representing respectively 120-year timber and the lower limit of the oldest age class — presumably 140–160 years plus — lie above the line and point *f*, representing the upper limit of the mature timber, lies on the line at point *B*.

If a rotation of 160 years is desired, the cut will get mature timber for about 63 years, and then will run into timber which will be 14 years under 160 years of age at point *c*, 15 years under age at *b* and 18 years under age at *a*. These lower cuts, however, are a long way in the future and the timber will not be seriously under age when reached.

The annual cut which can be counted on for continuous production can be read directly from the diagram. The mature timber occupies 61 acres of the 160 sample. Therefore, this mature timber should be made to last 61 years and the cut is, therefore, $\frac{150{,}000 \text{ M.}}{61} = 2{,}460$ M. per year, after which the present 80–120-year class will be mature and cutting can proceed in that timber. This cut can be annual or periodic, as management decides, but the total removed during the period should not exceed the annual allowable cut of about two and one-half million feet as calculated above, unless the management policy changes in the direction of a lower rotation.

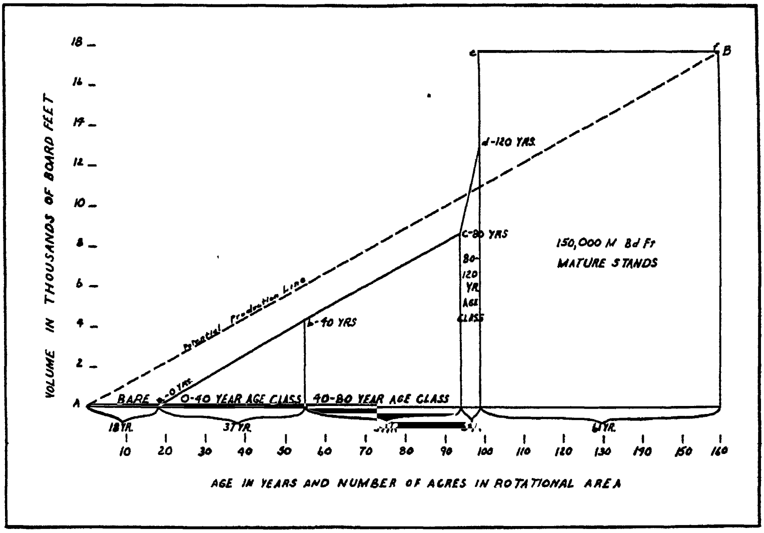

FIG. 3

If a rotation of 160 years is not in accordance with the policy of management, and if a shorter rotation is desired for either technical or financial reasons or both, diagrammatic presentation of the data for a rotational area of 120 acres and years will aid in fixing the allowable cut in mature timber (see Fig. 4).

In this diagram the "potential production line" *A–B* rises over a period of 120 years from 0 to the volume indicated as the average for timber 140 years and over in age, or 17,650 board feet per acre. Whereas this volume is presumably attainable on a rotation of 160 years, it is questionable as a yield at 120 years. However, whether this amount is or is not correct for the yield of 120-year timber has no bearing on the rate of cutting to adopt at once for such sustained yields as may be possible in the future on the chosen rotation. Points *a*, *b* and *c* are age points read from the potential production line and their location with reference to it and the corresponding age ordinate will indicate plus or minus age timber at those points when cutting reaches them on a rotation of 120 years, regardless of the pitch of the line *A–B*.

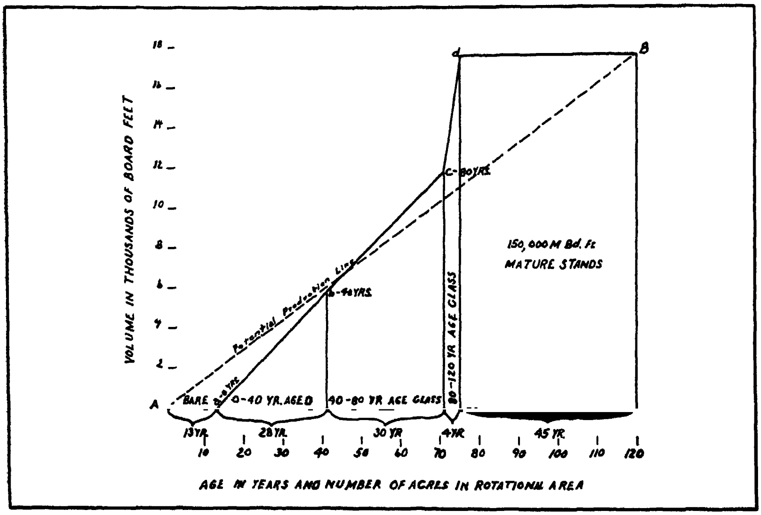

FIG. 4

In this case it is to be noted that cutting for continuous production can proceed for 79 years, or up to point *b*, without the necessity of cutting any timber less than 120 years of age. Thereafter the cut will come from timber ranging from 120 years of age down to 107 years of age during a 28-year period and from then until the end of the first rotation will get only what timber it has been possible to raise on the present bare and burned-over areas. The annual cut in mature timber which is allowable if continuous production is required can again be read from the diagram. The mature timber occupies 45 of the representative 120 acres and should, therefore, be made to last 45 years and the annual allowable cut is, therefore, $\frac{150{,}000 \text{ M.}}{45}$, or 3,335 M. per year. After the cut in timber at present mature is exhausted, timber which is now 80 to 120 years of age will be due for cutting and it will then be 125 to 165 years of age. Thereafter the cut may be expected to fall during a 5- to 10-year period to whatever yield is possible on a 120-year rotation and be maintained at that amount until 79 years from now, when timber of less than 120 years of age will have to be counted upon for the cut.

The method as described above makes no attempt to predict the yield from stands not at present mature, but only to regulate cutting in the mature stands, so that they will last until the younger stands have reached maturity at the chosen rotation. Obviously the yield which will be obtained from the younger stands will be governed by their stocking and the normal yield obtainable at rotation age. If normal yield at rotation age is known, then this amount should govern the pitch of the potential production line *A–B* on the diagram instead of the known volume per acre of the present merchantable stands.

The rate of cutting in timber now mature will be the same, but it will then be possible to read from the diagram the yields to be expected from timber at present immature by multiplying the percentage that their stocking is of normal by the yield indicated at the age they will attain when cut.

University of Michigan

FUR BEARERS IN MICHIGAN'S FOREST AREAS

HARRY D. RUHL

THE carnivorous fur bearers found in Michigan's forest lands range so widely, their numbers vary so much from year to year, and there seem to be so few of the limiting factors under the control of the forest management that revenues from their fur are not easily made an important part of the forest income.

Herbivorous fur bearers, such as the muskrat and the beaver, are more restricted in their habitats. Because muskrats and beavers are not hunted for sport or so violently accused of destroying desirable species of animal life as are the carnivores, their management and control would appear to offer better opportunities.

Open marsh lands in forest areas may, in many places, pay a part of the costs of forest management. Dry marshes, timbered swamps, leatherleaf bogs and deep open-water areas support comparatively few muskrats. Lily-pad areas may supply a crop of four to five muskrats per acre each season. Cat-tail stands, rice beds, arrowhead beds and sedge areas with some water deep enough for winter use of the muskrats may maintain a sufficient stock so that a surplus of six to eight per acre may be removed each year. According to reliable data, the annual catches sometimes go as high as ten to twelve muskrats per acre.

On well-stocked areas, trappers will usually catch the "rats" and care for the pelts for half of the crop, so that average net returns to the landowner of from three to five dollars per acre per year from muskrat furs are often practicable.

Areas suitable for muskrats are usually satisfactory for waterfowl, and the waterfowl hunting rights often rent for as much as one to two dollars per acre per year.

Beavers are increasing and extending their range in most of the wild-land counties of the Lower Peninsula. As beavers increase, the number and variety of places where there is damage to timber, roads, railroads, culverts, drains, water supplies and farm crops increases. The annual cost of "nuisance beaver control" is increasing, so that Michigan now has another important problem in wild-life management.

If there is no open season for trapping beavers, and if the present policy of live-trapping nuisance beavers and removing them to other waters is continued for a few more years, most of the waters in the larger forest tracts of Michigan will be stocked.

The best available estimates are that there are more than 10,000 miles of streams, rivers and inland lake shores in the wild-land areas of Michigan, most of which are suitable for beavers. It is not to be expected that at any one time beavers will occupy or use all of this water, but it is believed that this is a conservative estimate of the water on which they may homestead. Unless adequate methods of restricting these animals to definite areas are developed and put into practice, it may be expected that any or all of this area may be used eventually by beavers.

Studies of beaver habits indicate that the dams usually raise the water level less than four feet and that "heads" of more than five feet are the exception. It is also known that, in regions where food supplies are plentiful, beavers seldom cut large numbers of trees farther than 300 feet from the edges of lakes and streams or from the water in their ponds and canals.

It is, therefore, fairly easy for the forester to study the contours along the streams and to approximate roughly the areas likely to be flooded and the areas which may be "logged" by beavers.

Only very rough estimates of the total area of Michigan which may be flooded and logged by beavers are possible, but probably it is conservative to compute the potential beaver "pastures" as three quarters of a million acres.

In October, 1928, two adult beavers were released on a small lake within a stone's throw of the keeper's residence on the Gladwin Game Refuge, so they could be observed under natural conditions. The cover around this lake was sparse, but there had been no beavers there for about thirty-five years. A tally of these animals on the lake in the fall of 1930 showed that there were four beavers approximately one and one-half years old and six kits, in addition to the original pair. At the present low fur prices, and after the cost of trapping has been deducted, the estimated net fur values which have accrued would be something over $100.

TABLE I

BEAVER CUTTINGS, HOUSE LAKE, GLADWIN GAME REFUGE
October 30, 1928 — June 13, 1929

Diameter in inches of the stump left by the beavers, usually 8 to 18 inches above ground	Number of poplars cut	Number of oaks cut	Number of alders cut	Total of all species
0 up to 1 *	99	4	18	121
1 up to 2	70	5	7	82
2 up to 3	58		3	61
3 up to 4	49			49
4 up to 5	21			21
5 up to 6	5			5
6 up to 7	2			2
7 up to 8	2			2
8 up to 9	1			1
9 up to 10	1			1
Total	308	9	28	345

* Stumps 1 inch in diameter were counted in the 1- to 2-inch class, etc.

Although no dams were constructed, I found that these two beavers, with little or no help from their four young of the year, had cut 345 trees between October 30, 1928, and June 13, 1929, a period of about seven and one-half months.

In coöperation with the Department of Conservation, G. W. Bradt, of the Department of Zoölogy, Michigan State College, made a detailed survey during 1930 of the beaver plantings made on state game refuges in 1928.

When he tallied the cuttings on this same area on May 29, 1930, about eleven and one-half months after the count shown in Table I, he found 1,040 additional trees had been cut by the beavers.

TABLE II

BEAVER CUTTINGS, HOUSE LAKE, GLADWIN GAME REFUGE
June 13, 1929 — May 29, 1930

Diameter in inches	Number of poplars	Number of oaks	Number of alders	Number of white birches	Number of cherry birches	Number of maples	Total
0 to 1 *	94	16	73	0	0	0	183
1 to 2	166	39	103	5	8	0	321
2 to 3	216	64	32	10	19	0	341
3 to 4	83	28	10	5	3	0	129
4 to 5	33	5	0	0	0	1	39
5 to 6	7	0	0	0	0	0	7
6 to 7	6	0	0	0	0	0	6
7 to 8	4	0	0	0	0	0	4
8 to 9	5	0	0	0	0	0	5
9 to 10	3	0	0	0	0	0	3
10 to 11	2	0	0	0	0	0.	2
Total	619	152	218	20	30	1	1040

* Stumps 1 inch in diameter were counted in the 1- to 2-inch class, etc.

Though detailed tallies were not made late in the fall of 1930, observations showed that the proportion of oaks cut had increased and that these beavers were beginning to "clean out" the available food supplies around the lake.

These tables show something of the food preferences of these beavers and of the total number of trees which a given number of beavers may cut. Additional tallies are being made in other places as opportunities occur to tabulate the number of trees which a known number of animals will cut under given conditions.

TABLE III

BEAVER CUTTINGS, HOUSE LAKE, GLADWIN GAME REFUGE
October 30, 1928 — May 29, 1930

Period covered	Percentages based on the number of trees cut					
	Poplars	Oaks	Alders	White birches	Cherry birches	Maples
Oct. 30, 1928 June 13, 1929	89.3–	2.6	8.1	0	0	0
June 13, 1929 May 29, 1930	59.5	14.6	21.0–	1.9	2.9–	0.1–

These trees were cut within 300 feet of the lake shore and no dams had been built. It is expected that part or all of this colony of beavers will move to another site during 1931.

The interest shown by citizens in these beavers since they were released would seem to outweigh any wild life or recreational values destroyed.

From a consideration of timber supplies, markets and cover for other wild life, has it been a good investment to allow these trees to be turned into fur? If no fires occur near this lake, how long will it be before the area will become stocked by natural reproduction, so that another crop of beavers may be produced on this lake? What, if anything, might be done profitably to hasten the recovery of beaver "pastures"? These and many other questions can and must be answered before any consistent and permanent policy as to beaver management in our forest areas can be applied.

Though beaver cutting usually is more or less selective, and in many places may materially assist forest reproduction by thinning out the "weed" trees, there can be no assurance that desirable trees will be left uncut, particularly where dam or lodge material is needed.

Since permanent flooding kills all kinds of Michigan timber, this effect may often be more serious. Stands of cedar around lakes and along streams often may have considerable timber value and be important cover for deer, grouse, snowshoe hares and other species.

If an intelligent and permanent plan for control and management of beavers is to be instituted, certain decisions must be made. Are foresters concerned with this part of the forest, or are they faced with so many pressing problems that they are willing to let this one go by default? Are the zoölogists and conservationists to settle such problems on the basis of wild-life and recreational values and with little or no consideration of present or potential timber values?

If foresters are unwilling to forget about this part of the forest or unwilling to decide that beavers have no general place in the forest areas, what formulas as to timber and cover equities shall be applied in deciding where beaver control is desirable?

DEPARTMENT OF CONSERVATION
LANSING, MICHIGAN

SOIL MAPS AS A BASIS FOR MAPPING ORIGINAL FOREST COVER

JETHRO OTTO VEATCH

THE statement that vegetation presents different aspects over the face of the earth is accepted as a simple elemental fact. Observation has further revealed that differences exist in composition and form in circumscribed or local areas, as well as in climatic regions. From an abstract point of view there is no limit to which differentiation can be carried. Plants have increased significance to man if these different forms and manner of occurrence which he recognizes can be given geographic interpretation, or, in other words, if they can be mapped in a manner analogous to the mapping of other things or groups of things in nature, as, for example, rocks or soils. Since, obviously, it is impracticable to map each individual species, a grouping for mapping purposes may be made upon a physiological or ecological basis, or may be based upon associations characterized by some particular species or by the dominance of one or more species, and this latter plan appears to be the most logical procedure for the smaller subdivisions, or mappable units. In the United States it is possible to map, with a fair degree of accuracy, the broad plant formations, such as the southeastern mesophytic evergreen forest, or the central deciduous forest, divisions which are regional in extent. Mapping of smaller units of vegetation is also possible where the virgin vegetation remains. There is, however, a large part of the country where the original vegetation cannot be mapped locally and in detail, since it has been obliterated by clearing of land for agriculture, by lumbering and by fire, and therefore no longer exists or exists only as poor remnants widely separated. In such areas detailed maps of the distribution of the original cover of vegetation would have great scientific and practical value not only to the forester or silviculturist, but to the ecologist, the geographer, the economist, the historian and the pedologist, and therefore would also have a cultural educational value.

Probably in only very few instances will early surveys, local histories and records provide information adequate for reconstructing the original cover in detail. Even in a forested region as recently lumbered over as northern Michigan it is doubtful whether the original forest cover could be reconstructed in detail on the basis of existing vegetation in conjunction with early surveys and records of lumber companies.

The idea occurred to the writer a few years ago [1] that in such cases the original cover of vegetation might be mapped by assuming that vegetational types possess a distributional equivalency to soil types. The steps in the reasoning were, in brief: (1) The distribution of vegetation in general is a function of climate; (2) Climate is also a causal factor in the character and distribution of soils; (3) Moisture and temperature are primary factors determining the nature of vegetation, and these same factors cause local differences in soils, that is, given the same moisture and temperature conditions prevailing over a great period of time, soils would have certain common characteristics regardless of the rock or parent material; (4) Studies on the evolution of soils suggest that there is a simultaneous development of soils and vegetation; (5) Plants obtain a great part of their nutrients from the soil and a certain nutrient condition, together with physical and chemical conditions, is more favorable or unfavorable for one particular species or group of plants than for another; (6) The time in general has been sufficient for adjustments to take place between the soil and the plant. The soil, especially the mature or normal soil for a pedologic province, should be a perfect expression of the action of the same natural factors which have determined the vegetation. On the basis of the preceding postulations one arrives at the conclusion that the reconstruction of the original vegetation may be accomplished simply by employing the boundaries of soil types for corresponding types of vegetation.

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[1] Veatch, J. O., "Reconstruction of Forest Cover Based on Soil Maps," *Quarterly Bulletin*, 10, No. 3, Michigan Agricultural Experiment Station, February, 1928.

In the practical application of the idea, however, one is forced immediately to make provisos and reservations. At the outset it is prerequisite that at least a few remnants of the original cover be available, in order that relationships between soil and vegetation may be established. The accuracy of the soil mapping must be presupposed since the vegetation map would, a priori, inherit the errors of the soil map. If the ecologic scheme of classification is made independently, the phytogeographic units and the units on the soil maps must be of the same order.

The soundness of the idea, in practical application, very evidently will depend largely upon the degree of consistency with which a particular type of forest is restricted to a particular type, or to types, of soil. In order to obtain some kind of statistical data which would tend to verify or disprove assumed relationships, notes were made from "use-of-the-land" surveys in different parts of southern Michigan. In this survey, strips one-half mile wide were run at irregular intervals, in which every separate field and tract of land was outlined and classified. The total surveyed amounted to 528 miles and was distributed over five counties.[2] The land surveys were compared with soil maps and the frequency with which any particular forest type occurred on each soil type was noted. The results are presented in Table I, and the phytogeographic units employed in the mapping are given in Table II.

Our studies indicate that a dependable but by no means perfect correlation exists between the forest types here outlined and the units, or types, of soils ordinarily shown on soil maps made on a scale of 1 or 2 inches per mile. In the table there are a number of instances of inconsistency in relation to soil. Though some of these can be accounted for by errors of location in both the soil mapping and land mapping, and some by errors in soil classification, there are other more important factors.

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[2] The field mapping was done under the direction of the author by R. E. Pasco and Arnold Baur, graduate students in soils, Michigan State College, partly as independent work in connection with soil surveying, and partly in coöperation with the Game Division of the Department of Conservation, State of Michigan.

TABLE I

Forest Types in Relation to Soils

Soil types (Closely related groups)	Forest types (Number of instances)						
	Maple beech	Oaks hick-ory	Oaks	Elm, ash, bass-wood	Silver maple, elm, ash	Pin oak, red maple	Tama-rack
Miami	109	18	20	4	0	0	0
Plainfield	5	5	35	13	0	0	0
Bellefontaine Coloma	25	3	71	3	0	0	0
Fox	3	0	13	3	0	0	0
Brookston	5	1	0	160	20	0	1
Berrien	13	6	5	39	3	4	2
Gilford	14	1	1	26	27	0	0
Bronson	11	3	11	5	8	0	0
Newton	2	0	1	21	9	3	0
Napanee Conover	52	17	0	88	15	0	0
Griffin	0	0	1	41	16	7	0
Hillsdale	27	3	28	3	0	0	0
Carlisle muck	0	0	0	38	162	0	26
Rifle peat	0	0	0	0	9	0	27

The correlation appears to be closest where the separate soil types appear in relatively large and uniform bodies, but, on the other hand, where the soils occur in small bodies complexly associated there is more likely to be a mixture of forest types and frequent occurrence of some particular species on a site where it is not normally found in considerable numbers. Where this condition exists it may be possible to work out corresponding soil and vegetational complexes. Where one soil occurs as a very small body included in a large body of another type, the vegetation of the dominant soil is very likely to spread over the minor. This is the explanation of most of the instances of the elm-ash-basswood type of forest on Plainfield sand. The sand occurred as very narrow elongated strips on land composed predominantly of wet clay soils.

TABLE II

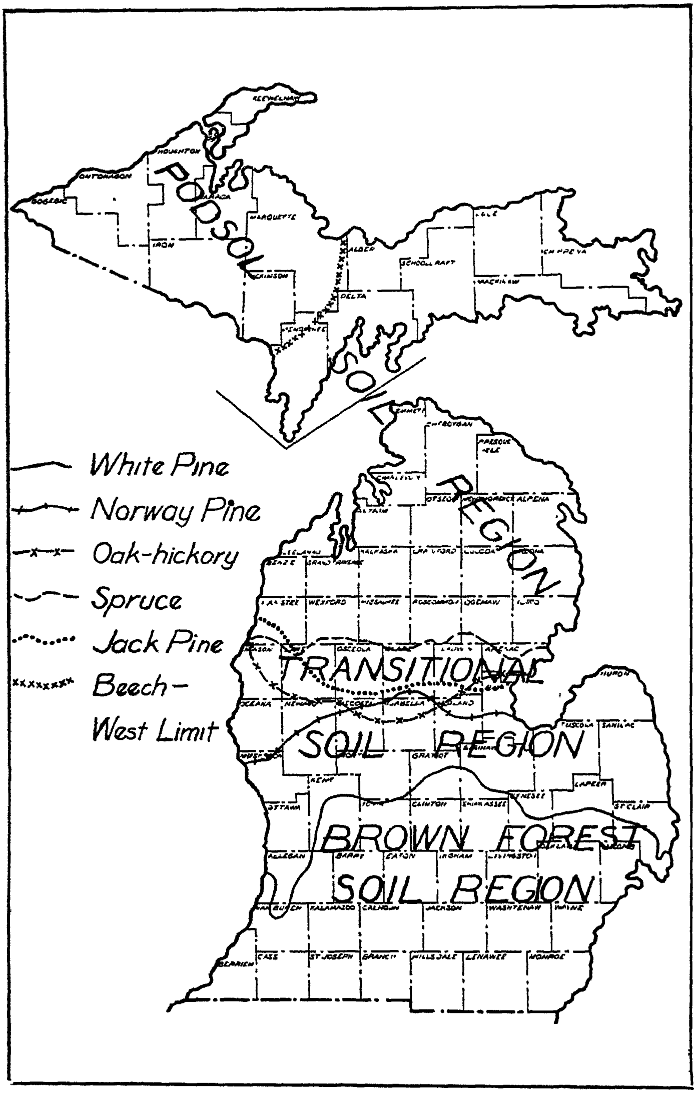
Phytogeographic Units of Southern Michigan

(Adapted to mapping on a scale of 1 to 2 inches per mile)

	DOMINANT CHARACTERISTIC	MINOR CHARACTERISTIC
Forest	1. Sugar Maple, Beech	Oaks, hickory, elm, basswood
	2. Oaks, Hickory	Elm, ash, basswood, sugar maple, beech, cherry
	3. Oaks	Hickory, beech, sugar maple
	4. Elm, Silver Maple, Ash, Basswood, Shagbark-hickory	Swamp white oak, beech, sugar maple, walnut, butternut, cottonwood, aspen, tulip, sycamore, tupelo
	5. Pin Oak, Swamp White Oak, Elm, Red Maple	White oak, aspen, white birch (conifers occasional to common)
	6. Silver Maple, Elm, Ash	Tamarack, aspen, willow
	7. Tamarack	Aspen, red maple, elm, willow, shrubs
	8. Complexes or Mixed Types (Various designations according to plants or sites)	
Shrub	9. Osier, Blueberry, Ilex *	Tamarack, aspen, willow, sedges
	10. Aspen, Willow, Birch *	
Prairie Marsh Bog (Classification incomplete)	11. Grass (dry prairies)	Burr oak
	12. Carex — Bluejoint	Willow, aspen, tamarack
	13. Leatherleaf, Blueberry, Sphagnum	Tamarack, aspen, spruce
	14. Buttonwood (ponds)	
	15. Cat-Tail	
	16. Water Lily	
	17. Lake Bulrush	

* There is some question whether these types represent original cover.

The geographic extent of any established correlation will have to be worked out by observation. As mapped at present, it is extremely doubtful whether any particular soil type is precisely the same in its chemical and physical characters throughout its range, nor is it at all likely that it will occur everywhere in exactly the same association with other soils. The areal extent of any particular correlation will probably be found to conform pretty



MAP 2. Map of Michigan showing limits of forest species and types in relation to the transitional belt of soils. The western limit of beech nearly coincides with a physiographic boundary and a boundary between two geologic groups of soils.

closely to natural land divisions, which are homogeneous in physiography, topography and soils, or which may be described as "soil associations." In Michigan the forest on the Miami types of soils is not the same in detail in the central part of the state as in the extreme southern part or as in Indiana and Ohio. Nor is the forest the same on certain sandy types in the southern part of the state as on those types in the central part, since in the first oaks, oak-hickory and certain species, as chestnut in the extreme southeast, may dominate or characterize the areas, whereas in the second white pine appears as an important constituent of the forest. It is probable that in our soil classification we have recognized too few soil divisions rather than too many in transitional belts, and therefore it is hardly to be expected that a perfect concordance in detail will be found in soils (as mapped in current and old soil surveys) and vegetation in transitional zones. In general, however, there should be a fairly close correspondence between transitional belts of vegetation and transitional soils. There is a strong suggestion of this in Michigan, as is shown on the accompanying map (Map 2).

It is the opinion of the author that it is possible to reconstruct the original cover of vegetation from a soil map with perhaps as near an approximation to the truth as by any other means. A sound knowledge of both ecology and pedology, as well as judgment and experience on the part of the worker, are presupposed.

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STEM FORM OF WHITE OAK*

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CONTENTS

Historical development of form studies
Definition of terms
Source and nature of data
Method of treatment
Form grouping
Stem form of white oak
The effect of certain factors upon taper
Root swell
Bark development
Form-class determination
Summary
Conclusion
Appendices
Literature cited

HISTORICAL DEVELOPMENT OF FORM STUDIES

METHODS of determining stem volumes of standing trees have been and still are of absorbing interest to foresters. Estimates of stem contents are required each time a forester takes an inventory of his working stock. Consequently, any device that will give accurate volumes with a minimum expenditure of labor is eagerly welcomed.

One of the earliest of these devices to come into common use was the volume table, which was suggested by H. Cotta in his work, *Systematische Anleitung zur Taxation der Waldungen* (Vol. 3, p. 6). In the early volume tables the assumption was made that trees of the same diameter and height possessed the same stem volume.

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* Contribution No. 28 from the School of Forestry and Conservation, University of Michigan. This investigation was carried out under the direction of Dean S. T. Dana of the School of Forestry and Conservation.

Contemporaneously with the origin of the conception of volume tables Oberforster Joh. Christ. Paulsen in 1800 introduced into a manuscript[1] the theory of form variation among trees of the same diameter and height. He expressed this variation as a reduction factor whereby the volume of a cylinder of given dimensions was reduced a certain amount to determine the volume of a tree of the same dimensions and of a given form (18, p. 202). Paulsen recognized three form factors, 0.75, 0.66 and 0.50, and he assigned trees to one or another of these three form classes on the basis of crown length.

Hossfeld, in 1812, took a step forward in the study of stem form when he determined a formula by which the reduction factor could be calculated.

Schwappach (28, p. 48) distinguished three varieties of reduction factors, or form factors, as they came to be called:

(1) The breast-high form factor he defines as the ratio between the volume of a tree stem and the volume of a cylinder of equal height and diameter at breast height. This form factor introduces error, since the actual height at which the base diameter is measured remains at a constant height of 1.3 meters above the ground for all trees. On trees that are short this may be one third of the total height, whereas on tall trees this may be no more than one thirtieth of the total height.

(2) The normal form factor overcomes this weakness by making the height at which the base diameter is measured a constant percentage of the total height. The normal form factor is defined as the ratio between the volume of a tree and the volume of a cylinder of equal height and diameter at a height of $\frac{1}{n}$ times the total height of the tree. In practice Schwappach states that n is most frequently given a value of twenty.

(3) The Riniker form factor, introduced by Riniker in 1873, is the ratio between the volume of the portion of a tree lying above the breast-high point and the volume of a cylinder having

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[1] This manuscript was published in 1845 in Hundeshagen-Klauprecht's *Beiträge zur Forstwissenschaft.*

a diameter equal to the breast-high diameter of the tree and a height equal to the length of the tree portion above breast height.

Schuberg (26) found in 1891 that the ratio between the diameter at the middle of the stem and the breast-high diameter could be used to determine corrections that should be applied to silver-fir volume tables in order to take form into consideration and to get more accurate volumes.

Almost simultaneously Kunze (14) proposed a formula for the calculation of the form factor. By this formula the form factor

$$f = \frac{d_{\frac{1}{2}}}{D} - c. \tag{1}$$

In this equation $d_{\frac{1}{2}}$ is the diameter at half the height of the tree, D is the diameter at breast height, and c is a constant that varies for different species. Kunze found the value of c to be about 0.21 for Norway spruce (*Picea Abies* Karst.) and about 0.20 for Scotch pine (*Pinus sylvestris* L.).[2]

In 1899 Schiffel (25) tested further the theory of Schuberg and concluded that as a form-determining factor the ratio between the diameter at mid-height and breast height was very satisfactory. This ratio Schiffel called the "form quotient," and grouped trees into form classes on the basis of the form quotient. Developing still further the formula of Kunze, Schiffel later arrived at a formula for tree volume based upon height, diameter and form.

$$V = h\,(0.16D + 0.66d_{\frac{1}{2}}). \tag{2}$$

In this formula V indicates stem volume, h is the height, D, the diameter at breast height, and $d_{\frac{1}{2}}$, the diameter at mid-height.

If any form factor is viewed from a purely theoretical standpoint it may be considered as the ratio between the volume of a solid generated by the rotation about the x-axis of a curve of the type

$$y^2 = px^r \tag{3}$$

and a cylinder of equal base diameter and height (18, p. 203). In this equation y is the ratio between any given diameter at a percentage distance of x from the tip and the base diameter. The nature of the rotation solid will depend upon the magnitude of r. When $r = 1$ the solid generated will be a paraboloid. A right circular cone will be generated when $r = 2$, and a neiloid when $r = 3$. It can be shown that the theoretical form factor[3]

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[2] See 28, p. 55.

$$f = \frac{1}{r+1}\left(\frac{l}{l-a}\right)^r. \tag{4}$$

Here r is the exponent of x in equation (3), l is the total height of the tree, and a is the distance from the ground to the point where the base diameter is measured.

In 1910 Jonson (9) made use of the logarithmic equation of Höjer to express the taper of Norway spruce stems:

$$\frac{d}{D} = C \log \frac{c+l}{c}. \tag{5}$$

In equation (5) d is the diameter at any point on the stem, D is the base diameter, l is the distance from the tip to the point at which the diameter d is measured, and C and c are constants that vary with the form class. Jonson computed the $\frac{d}{D}$ relationship at each tenth of the stem length above breast height for the sample Norway spruce trees with which he was working, and concluded that, if trees were grouped into classes on the basis of the form quotient, all trees falling into the same form class would exhibit similar form. This means that large trees and small trees are built according to the same pattern, and that the index to the form of any tree stem is the form quotient.

He arbitrarily selected form classes five units in width, the class mark[4] being 0.55, 0.60, 0.65, 0.70. For each form class he computed the constants C and c in Höjer's equation.[5] He chose these constants for each form class in such a way that the $\frac{d_{\frac{1}{2}}}{D}$ ratio gave the class mark for that form class. Having determined the constants for the several form classes, Jonson substituted those values for l in equation (5) that would give a diameter ratio at each tenth of the stem above breast height. In this manner a set of theoretical diameter ratios was constructed for each form class. Jonson divided his sample trees into form classes 0.60, 0.70, 0.80, and compared the actual diameter ratios determined by measurements on the tree stems with the theoretical ratios calculated by means of Höjer's equation. He found a very satisfactory comparison, and concluded that the equation of Höjer could be used to represent the form of Norway spruce.

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[3] For a complete development of this formula see Appendix A, p. 324.

[4] For a definition of class mark see p. 287.

[5] The details of the procedure used in determining the constants in Höjer's equation are given in Appendix B, pp. 327–328.

In a manner similar to the one used to calculate formulae for the theoretical volume and form factor of a paraboloid,[6] Jonson calculated formulae for the theoretical volume and form factor of a body generated by the rotation of Höjer's curve about its l-axis. Later he prepared tables that give tree volumes for trees of various diameters, heights and form classes (12).

Jonson also calculated diameter ratios from actual diameter measurements on Scotch pine. These measurements were taken at each tenth of the stem length above breast height. When he compared these ratios with the theoretical ratios given by Höjer's equation he found an appreciable disagreement in the upper portion of the stem (10, p. 291). However, by the addition of a "biologic" constant to the equation he secured a good agreement with the observed diameter ratios. The modified equation is

$$\frac{d}{D} = C \log \frac{c + l - 2.5}{c}. \qquad (6)$$

The symbols used in this equation are the same as those that were used in equation (5).

Jonson realized that in order to make his application of Höjer's equation practicable he must devise some way to determine in the woods the form quotient of any tree. Using the theory of Metzger, which posits that the bole of a tree is constructed in a form that will best withstand the pressure of the wind against the tree crown, he determined the form class to which a tree belongs by the height of the form point (11, p. 244). According to

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[6] See Appendix A, p. 324.

Jonson, the form point height is the height of a paraboloidal girder which offers the same resistance to bending that is offered by a tree of similar diameter, and form in the lower portion. The girder is formed by the rotation of the parabola

$$\frac{d}{D} = \sqrt[3]{\frac{l}{L}}. \tag{7}$$

In this equation L and l are distances from the top of the paraboloid at which D and d are measured.

Jonson determined the theoretical form point height for form class 0.70 in the following manner: Theoretical diameter ratios computed by the use of Höjer's equation for form class 0.70 show that at two tenths of the height of the stem above breast height the theoretical diameter ratio is 39.95, and at breast height the ratio is 100. To determine the equation of a cubic paraboloid whose height is x, whose base diameter ratio is 100 and whose diameter ratio at x–20 is 89.95, substitution of these known values is made in equation (7), giving

$$\frac{89.95}{100} = \sqrt[3]{\frac{x - 20}{x}}$$

$$\overline{0.8995^3} = \frac{x - 20}{x}$$

$$x = \frac{20}{1 - (0.8995)^3}$$

$$x = 73.5.$$

The heights of the girder for other form classes were obtained by determining from Höjer's equation the theoretical diameter ratio at two tenths of the height of the stem above breast height. This ratio was substituted in equation (7), and x was computed as for form class 0.70. Since the diameters of the girder and the curve rotation body agree very closely in the lower portions, the height at two tenths above breast height is very probably an arbitrary one.

Jonson also developed an empirical equation by means of which the form point height may be computed for any form class (11, p. 255):

$$F_p = \left(q - 0.081 + \frac{0.07^{(7)}}{h - 1.3}\right)^2 \times 1.896. \tag{8}$$

In this equation F_p is the percentage form point height, h the total height of the stem in meters, and q the form quotient inside bark. Equation (8) may be rewritten as follows:

$$q^{(8)} = 0.726\sqrt{F_p} + 0.081 - \frac{0.07}{h - 1.3}. \tag{9}$$

From the equation in this form the form quotient inside bark can be calculated when the form point is known.

Figure 5 presents diagrammatically the paraboloidal girder with reference to the tree stem and shows the girder length to be about 73.5 per cent of the stem length. It also shows that in the lower portion of the stem the girder and stem have very nearly the same diameter ratios.

The tip of the girder is considered to be the point at which the force of the wind against the crown is concentrated. For practical determination in the woods the height of the form point is considered the geometric center of the outline of the crown, and the height of this point is measured with the aid of a Christen hypsometer. Since the

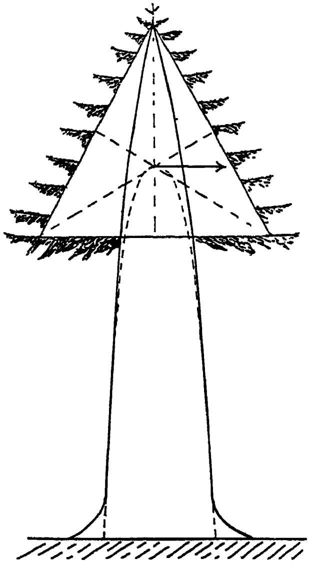

FIG. 5. A tree stem of form class 0.70 containing a theoretical girder of equal length (from Jonson)

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[7] In the original publication 0.07 is erroneously given as 0.70. See 13, p. 184.

[8] If the form class outside bark is desired for thick-barked trees this expression must be corrected by a factor of the type $\frac{1.0p_1}{1.0p_o}$, where p_1 indicates the double bark as a percentage of the diameter inside bark at the middle of the stem, and p_o the same percentage at breast height.

outline of the crown is frequently very irregular, this determination can be only approximately correct.

Petrini (21, p. 170) has investigated the accuracy with which the form point can be determined by different estimators. His conclusions are that different estimators arrive at different average form points for any given stand, but that the standard deviation of such averages is ± 1.17 form-point units[9] from the mean of the average form points of all estimators. The average form points obtained by different estimators may differ somewhat more from one another. In this case Petrini found the standard deviation to be ± 2.0 form-point units. He also concluded that for a single tree the standard deviation of the estimates of form point by several estimators was ± 3.1 form-point units.

Tirén (29, p. 391) advanced the following equation for determining the diameter ratio at any height:

$$\frac{d}{D} = P \log\left(\frac{x + \sqrt{k^2 + x^2}}{k}\right). \tag{10}$$

In this equation d and D are upper and breast-height diameters respectively, P and k are constants, and x is the percentage distance from the tip.

Petterson (24, p. 39) proposed a modification of Höjer's equation in which he used only one curve of the form

$$y = \log x^{(10)} \tag{11}$$

instead of a series of curves, each of which has a different set of values for C and c.[11] In equation (11) y is the $\frac{d}{D}$ diameter ratio where d is measured at any percentage distance, x, from the tip. The curve of this equation is shown in Figure 6.

The units are seen to be the same for both the x- and y-axis. When $y = 0$, $x = 1$, and for values of x smaller than 1, y is negative. The portion of the curve above the x-axis is assumed by

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[9] A form point unit is defined as 1 per cent of the height of the tree.

[10] For a development of the equation of Petterson see Appendix C, p. 328.

[11] See Appendix B, p. 327.

Petterson to represent the form of the tree stem. The tip is always at the point $x = 1$, but the base of the tree falls at varying values of x. As the base of the tree approaches the value $x = 1$, the form quotient becomes smaller, until when the base reaches the point $x = 1$ the form quotient reaches the limiting value of 0.50.

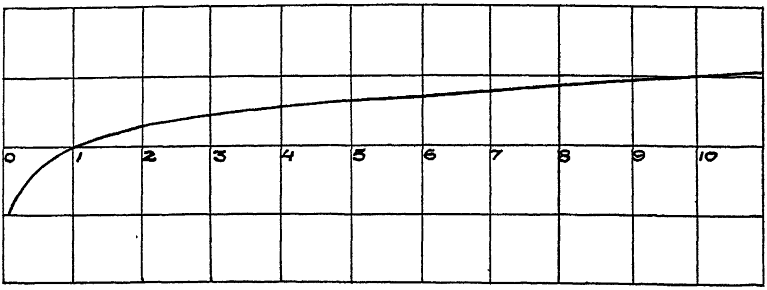

FIG. 6. Curve of equation $y = \log x$

Behre (1, p. 681) has proposed an hyperbolic curve[12] for the expression of stem form:

$$y = \frac{x}{a + bx}. \tag{12}$$

In this equation y is the ratio between any given diameter and the base diameter, x is the percentage distance of the given diameter from the tip to breast height, and a and b are constants that vary with the form class. The constants in Behre's equation are very easily computed; their algebraic sum is always unity.

Jonson (13, p. 172) compares the diameter ratios as they are computed from the formulae of Höjer, Höjer-Jonson, Tirén, Behre and Petterson. His summary shows that the differences between the diameter ratios as given by the several formulae do not amount to 1 per cent in the lower 60 per cent of the stem length. Above that height variations as great as 4 per cent occur. Höjer's unmodified equation gives the highest ratios, but the other four equations agree rather well among themselves. The conclusion is that the results are very nearly the same if any of the last four equations is used.

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[12] Langsaeter (15, p. 141) has expressed Behre's equation in the form $y = 1 - \frac{1}{x}$.

Very recently Heijbel (8, p. 144) has attempted to show that no single curve can accurately portray the stem form of Scotch pine. He has fitted three separate curves to different portions of the stem. His investigation shows that the portion of the stem from the root swell to the crown is best represented by a tangent equation.[13] The deviations in the crown portion of the stem are sufficient to cause Heijbel to compute a correction formula, which gives the correction that should be applied to the tangent curve in order to secure better agreement with actual tree form in the portions of the stem lying within the crown. Heijbel believes that the trunk form from the stump to 10 per cent of the height is best represented by a power equation, and accordingly develops one that represents the taper of Scotch pine in this portion of the stem.

From this brief historical review it is seen that European investigators have for many years pointed out the importance of stem taper in accurate tree volume determination. In American forest practice, on the contrary, the volume tables most commonly used are based upon diameter and height only. There are, however, variations other than the taper in the upper portion of the stem that influence the accuracy of American volume tables.

Unusual variations in diameter at breast height are of greater significance than variations elsewhere on the stem, for, according to the present practice, tables of volumes of trees of given heights and breast-high diameters show the same volumes for two trees if they have the same heights and diameters. Root swell, however, if it extends above breast height, might easily add one inch to the breast-high diameter of one tree and not influence the diameter of the other appreciably. The first tree, therefore, is in a diameter class that is one inch greater than the diameters of the upper sections warrant, and the tabular volume is in excess of the true volume.

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[13] For a development of the formulae of Heijbel see Appendix D, p. 331.

Since foresters are primarily interested in the wood content beneath the bark,[14] the influence of bark thickness upon the measured diameters outside the bark is also important. Especially is this true of the breast-high measuring point. Measurements on standing trees are customarily made on the bark, and an accurate conception of the thickness of bark is essential to satisfactory determinations of wood content.

Form studies are, therefore, of significance, since through them foresters arrive at systems of tree-volume determination that permit greater accuracy than could possibly be obtained if form were disregarded. The rate of taper of the main stem and the effect of root swell and bark thickness on the principal diameter measurement are the chief factors that cause variations in volumes of trees having the same height and diameter at breast height.

The work done heretofore to develop mathematical equations as expressions of tree form has been confined almost entirely to coniferous species. For these species the form-class method has seemed to be very helpful in increasing the accuracy of wood-volume determination. Foresters have been seeking some method of caring for form in the broad-leaved species and have hoped that the form-class method might apply to them. The characteristic habit of growth of conifers gives them a regular, consistent taper, whereas most hardwoods have no such regularity in form. Large branches occurring irregularly introduce this variability.

Hawley and Wheaton (6, p. 7) have made use of the form-class method in their study of New England hardwoods. Hedeby (7, p. 193) began a comprehensive study of the form of oak[15] in Sweden; he recently published a preliminary report upon his researches. In this report he considered only oak grown in a relatively closed forest condition and under intensive forest management. As a result, his basic material is more regular in its taper than if he had considered also trees from open stands. From a meager sample of fifty-five closed-stand oaks he concluded that Höjer's equation, modified by the addition of a certain "biologic" constant, fits the oak data relatively well. For open-stand oak he offers no solution in his preliminary work.

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[14] For particular species, such as hemlock and oak, foresters may be interested in determining annual increments and total yield of bark, as well as of wood, since the bark value for tannin is a matter of importance.

[15] Two species of oak are indigenous to Sweden, *Quercus pedunculata* Ehrh. and *Quercus sessiliflora* Sm.

Second-growth stands of hardwoods in the eastern United States do not generally fall into the class of material upon which Hedeby made his preliminary report. Our stands are not usually managed, and after logging "wolf" trees have been allowed to remain. As a result, such stands are extremely irregular in age, development and form. It is in this type of stand that American foresters wish to measure wood volumes as accurately as possible. This paper presents the results of an investigation to determine the possibility of applying the form-class method of volume determination to white oak[16] as it is found in the second-growth hardwood stands of the eastern United States.

DEFINITION OF TERMS

Average of ratios. — For any group of trees the average of the ratios between the diameter at any given height and a base diameter at any arbitrary height. Algebraically, this is equivalent to

$$\frac{\frac{d_1}{D_1} + \frac{d_2}{D_2} + \frac{d_3}{D_3} + \frac{d_4}{D_4} + \dots + \frac{d_n}{D_n}.}{n}$$

Ratio of average diameters. — For any group of trees the ratio between the average diameter at any given height and the average base diameter, chosen at an arbitrary height. Algebraically,

this is $$\frac{\frac{d_1 + d_2 + d_3 + d_4 + \dots + d_n}{n}}{\frac{D_1 + D_2 + D_3 + D_4 + \dots + D_n}{n}}.$$

Bark percentage. — The ratio between the double-bark thickness at any point on the tree stem and the diameter on bark at that point.

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[16] *Quercus alba* L.

Class mark. — The mean of the greatest and least variates that can occur in a given class.

Genuine form quotient. — The ratio between the tree diameter inside bark at four tenths of the distance from the tip to breast height and the corresponding diameter at eight tenths of the distance from the tip to breast height.

Genuine form class. — A range of genuine form quotients. In this paper the genuine form class takes the name of the class mark and each class is 0.05 wide. Consequently the 0.65 genuine form class includes all trees having a genuine form quotient ranging from 0.63 to 0.67 inclusive.

Riniker genuine form factor. — The ratio between the volume of a tree and the volume of a cylinder having a height equal to the height of the tree above breast height, and a diameter equal to the tree's diameter at eight tenths of the distance from the tip to breast height.

Standard deviation. — The square root of the mean of the squared deviations from the arithmetic mean. Algebraically, this is expressed as

$$\sigma = \sqrt{\frac{\Sigma d^2}{n}}.$$

Standard deviation of error of prediction. — The square root of the mean of the squared deviations from a line or plane of average relationship.

Standard deviation of a mean. — The standard deviation of the sample divided by the square root of the number of variates occurring in the sample. Algebraically, this is

$$\sigma_m = \frac{\sigma}{\sqrt{n}}.$$

SOURCE AND NATURE OF DATA

The data upon which the results of this study are based were obtained from the files of the Branch of Research of the United States Forest Service; they consist of separate cards for individual trees. Upon these cards are tabulated the stem diameters inside and outside bark at stated distances above the ground. Additional information, such as locality in which the tree grew, age, crown class, clear length and width of crown, was given for some or all trees. From these data, measurements on 351 trees were found to be sufficiently complete for the purposes of this study. Most of these trees were from the following localities: southern Ohio, southwestern Connecticut, eastern West Virginia, New York and a few points in Maryland and Tennessee. Their distribution throughout the geographic range and by diameter and height classes is shown in Table I.

Plate XXVII shows an area of nearly pure white oak near Wardensville, West Virginia. This stand is practically even-aged; it followed a clear cutting made about 1775. A selective cutting was made about 1875, at which time species other than white oak were removed. Since that time the white oak alone has occupied the area.

The stand shown in Plate XXVIII is largely chestnut oak (*Quercus montana* Willd.) and black oak (*Quercus velutina* Lam.), also in the vicinity of Wardensville, West Virginia. In this type of stand white oak is commonly found.

METHOD OF TREATMENT

The diameter measurements at varying heights on the sample trees were made to the nearest tenth of an inch; in order to reduce these points of measurement to a comparable basis, the diameters inside and outside bark were plotted over height, one graph being made for each tree. Smooth curves were made to pass through each of the plotted diameters, one curve for the diameters inside bark, and one for diameters outside bark. From these curves were read diameters inside and outside bark for each tree at each tenth of the height of the stem above breast height.[17] The double-bark thickness at each measuring point was obtained by subtracting the diameter inside bark from the diameter outside bark.

Diameter ratios were calculated for each diameter inside bark by dividing the diameter at any tenth of the distance from the

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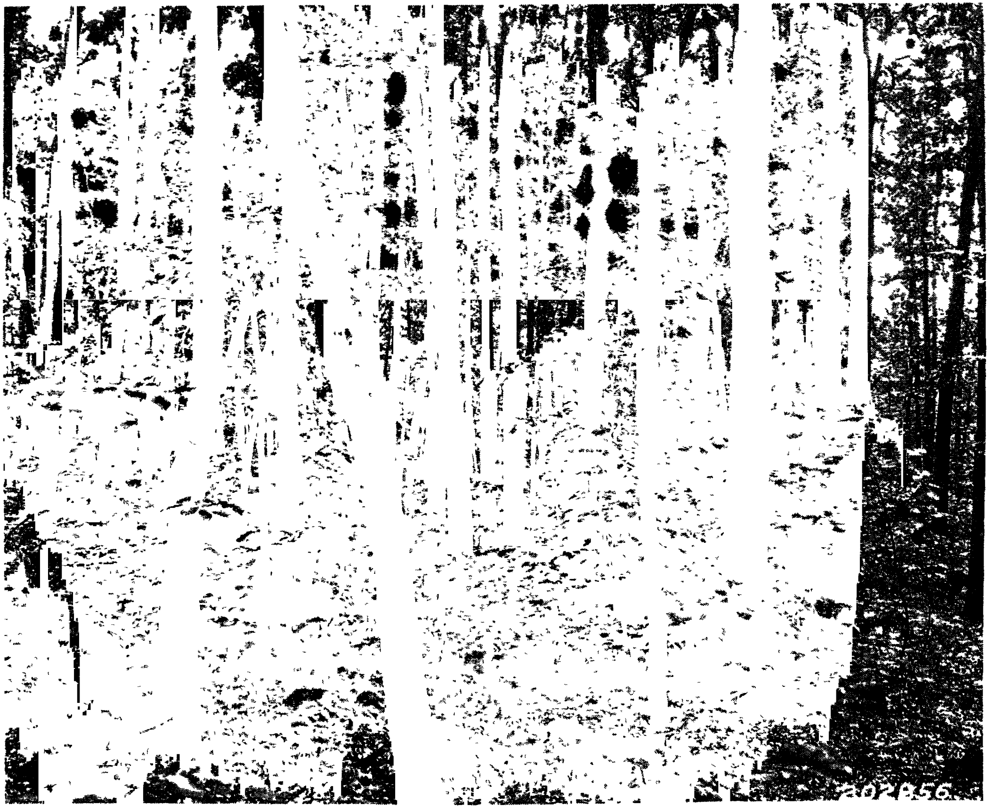
[17] Through the remainder of this paper, unless a specific statement to the contrary is made, only the portion of the stem lying above the breast-high point is considered.

PLATE XXVII

Photograph by U. S. Forest Service

White oak in practically pure stand near Wardensville, West Virginia

PLATE XXVIII



Photograph by U. S. Forest Service

Mixed stand of black oak and chestnut oak near Wardensville, West Virginia

TABLE I

DISTRIBUTION OF TREES BY LOCALITY, AND BY DIAMETER AND HEIGHT CLASSES

Diameter at breast height in inches	GEOGRAPHIC LOCATION																				Total
	Connecticut					New York			West Virginia					Ohio				Other locations			
	Height classes *																				
	40	50	60	70	80	20	30	40	50	60	70	80	90	40	50	60	70	50	60	70	
	Number of trees																				
3	..	..	..	..	..	9	13	..	..	..	..	..	..	..	...	..	..	..	..	..	22
4	..	..	..	..	..	5	13	1	..	..	..	..	..	..	..	..	..	..	..	..	19
5	..	..	..	..	..	..	3	14	..	..	..	..	..	3	2	..	..	..	..	..	22
6	..	..	..	..	..	..	1	9	1	..	..	..	..	7	5	..	..	..	..	..	23
7	5	2	..	..	..	..	..	3	1	..	..	..	..	7	23	4	..	1	..	..	46
8	10	22	..	..	..	..	..	1	..	..	..	..	..	2	13	13	..	..	1	1	63
9	6	19	4	..	..	..	..	..	..	1	..	..	..	..	..	8	1	..	1	..	40
10	..	15	3	..	..	..	..	..	..	..	..	1	..	..	..	4	1	..	..	1	25
11	1	13	4	..	..	..	..	..	..	..	1	4	..	..	..	..	..	..	..	1	24
12	..	3	2	..	..	..	..	..	1	..	1	1	..	..	..	..	1	..	..	..	9
13	..	3	1	..	..	..	..	..	..	..	4	4	2	..	..	..	..	..	..	..	14
14	..	..	3	..	..	..	..	..	..	..	3	4	2	..	..	..	1	..	..	..	13
15	..	..	1	..	..	..	..	..	..	..	1	4	3	..	..	..	..	..	..	..	9
16	..	1	1	..	1	..	..	..	..	..	..	5	1	..	..	..	..	..	1	..	10
17	..	..	..	..	..	..	..	..	..	..	1	4	2	..	..	..	..	..	..	..	7
18	..	..	..	..	..	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	3
19	..	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2
	22	78	20	1	1	14	30	28	3	1	14	27	10	19	43	29	4	1	3	3	351

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* The twenty-foot height class contains trees whose heights are 19.6 to 29.5 feet inclusive. Other height classes are similarly limited.

tip by a base diameter taken at eight tenths from the tip. In this form diameters of trees of any size can be compared.

The computational labor of this study was materially lessened by the use of the Hollerith sorting and tabulating machines. Three cards were made for each tree. The first eighteen columns were identically punched for each of the three cards of each tree. The headings used for purposes of classification were: tree number, genuine form class, diameter at breast height in inches, total height of tree in feet, crown class, breaking point — that is, the point at which occurred a sharp break in the stem curve — geographical location, age, and the ratio between crown length and total height of tree. The last twenty-seven columns were punched differently for each of the three cards of each tree. On the first card in these columns were punched the actual diameters in inches at each tenth of the height of the stem. On the second card in these columns were punched diameter ratios at each tenth of the height of the stem. On the third card were punched double-bark thicknesses in inches at each tenth of the height of the stem.

In the analysis of the data the cards were sorted on the basis of the several variable factors, and totals of bark thickness, actual diameters and diameter ratios were easily obtained from the Hollerith tabulating machine.

In the earlier studies of tree form no satisfactory method of measuring root swell had been discovered, and consequently its influence upon the breast-high diameter was not determinable. Since the effect of a swollen base diameter is carried to the ratios at all the tenths of height, it is very important that the effect of root swell be eliminated. Behre (1, p. 678) has done this graphically by prolonging the main curve of the upper stem downward to the breast-high point. Hawley and Wheaton (6, p. 9) have also used this method in their work.

Hedeby (7, p. 202) computed the diameter free from root swell, i.e. the "normal" diameter breast-high for each tree, by passing a parabola through the ratios that represented the diameters at five tenths and nine tenths of the tree's length from the tip to breast height. In doing this he made the assumption that root swell in oak does not extend up the stem as far as a point one tenth above breast height, and also that a parabolic curve will fit the normal curve of the stem in this portion of the trunk.

The stem curve of oak is not typically as regular as that of the western yellow pine (*Pinus ponderosa* Laws.) with which Behre (1, p. 678) worked, and the white oak stem curves shown in Figures 7*a*–*c* illustrate the difficulty of prolonging the curve for the upper portion of the stem downward to obtain graphically the normal breast-high diameter of any tree. Langsaeter (15, p. 129) quotes Heibel as having used the diameter nine tenths from the tip[18] as the base for his ratio system. Langsaeter himself (15, p. 129) used as the basic diameter for his ratios the diameter at eight tenths from the tip. Realizing that a base plane lying above the zone of root swell has very real advantages over approximate methods of determining normal diameters, I have chosen the diameter at eight tenths from the tip as the base diameter for the system of ratios used in this study.[19] Since the two diameters that comprise the form-class determining ratio should not lie too close together, the upper diameter of this ratio was chosen at four tenths from the tip.

This ratio was used in grouping the test trees into genuine form classes. For each genuine form class the average of the ratios at each tenth of the stem length was determined by adding the ratios and dividing by the number of trees in the class. This procedure may be open to objection on the ground that the average of a set of diameter ratios at a given height does not equal the ratio of the average diameter at that height to the average base diameter. Expressed algebraically, this is

$$\underset{\textstyle A}{\frac{\dfrac{d_1}{D_1} + \dfrac{d_2}{D_2} + \dfrac{d_3}{D_3} + \dots + \dfrac{d_n}{D_n}}{n}} \neq \underset{\textstyle B}{\frac{\dfrac{d_1 + d_2 + d_3 + \dots + d_n}{n}}{\dfrac{D_1 + D_2 + D_3 + \dots + D_n}{n}}}. \qquad (13)$$

---

[18] Here the portion of the tree above the stump is considered, rather than the portion above breast height.

[19] Figure 9, p. 313, shows that for white oak the diameter at eight tenths of the tree's length from the tip is free from the effects of root swell.

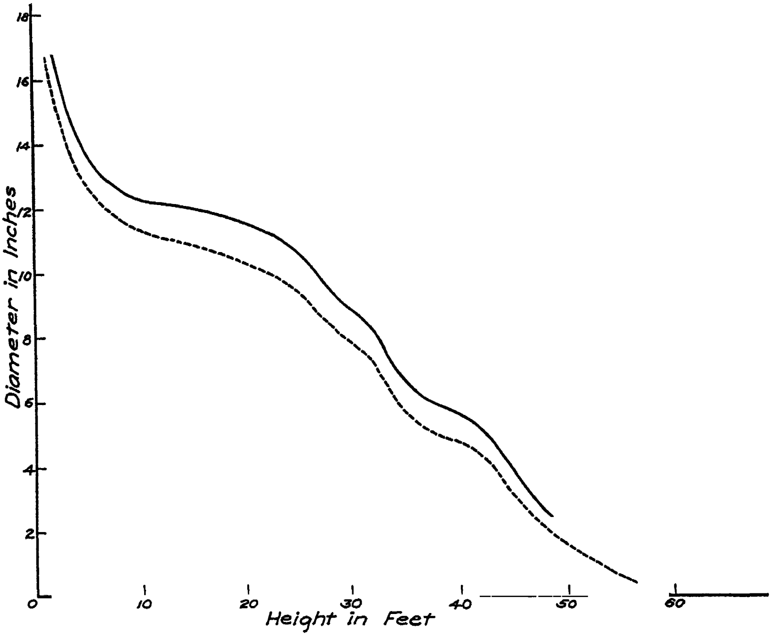

Fig. 7a. Stem curves of white oak: - - - inside bark; —— outside bark

In any application of the results of such averaging to reconvert ratios to diameters the amount of inequality of these two expressions may be of importance.

The process of reconverting ratios to diameters is sometimes employed to determine the diameter at a given height on trees of given diameter, form and total height. Wright uses this procedure (31, p. 113) as follows: "Read off on the plotted percentage taper curve the percentage diameters at these heights. Convert these percentage diameters to inches by multiplying diameter at breast height inside bark by the corresponding percentage diameter." For example, it may be desired to know the diameter at each tenth of the stem length for an average tree of a given species in the eight-inch diameter class, the fifty-foot height class and form class fifty. It is assumed that previous investigation has determined that the taper of the species

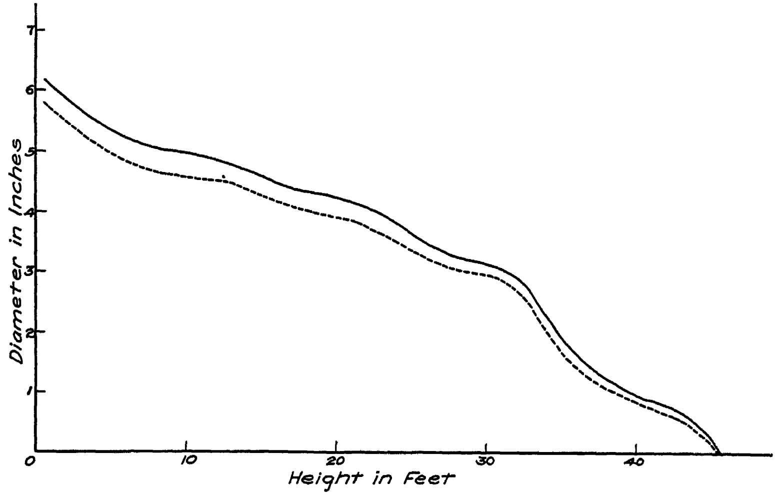

FIG. 7b. Stem curves of white oak: - - - inside bark; —— outside bark

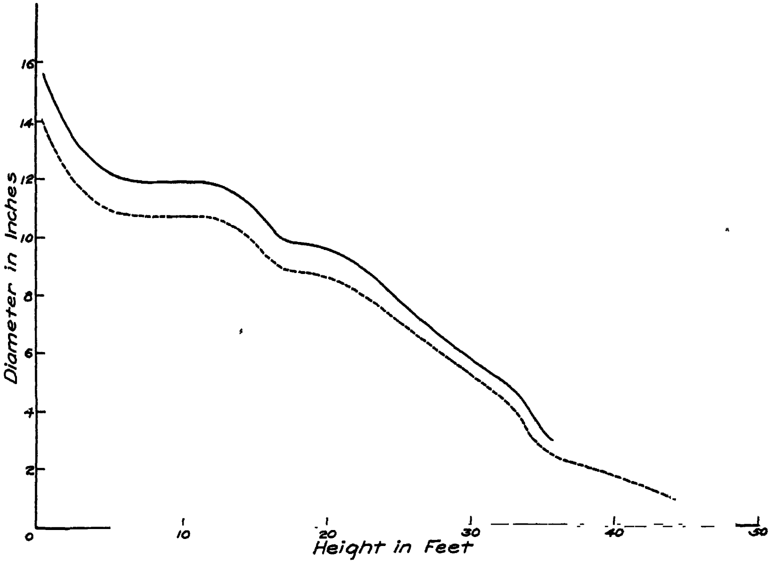

FIG. 7c. Stem curves of white oak: - - - inside bark; —— outside bark

conforms to the particular type of curve used. From the curve for form class fifty is read the average diameter ratio at the several heights, and this diameter ratio is converted to diameters by multiplying each ratio by the diameter at breast height, which is the base of the system of ratios used by Wright.

If trees in general conformed absolutely to any given stem curve, accurate volume determinations would be much simplified. The standard practice is to show that any species conforms relatively well to a certain stem curve by listing for each tenth of the stem's length the deviations of the average diameter ratios from the calculated ratio as given by the equation. If the deviations are small, the curve is said to express the stem taper well. An examination into the method of obtaining the average ratio for any tenth of the stem's length will show that certain fundamental errors may exist in the deviations of the averages of observed ratios from the ratios read from curves.

To show how these errors may influence the average diameter ratio at any given tenth of height, ten ratios at seven tenths of the tree's length from the tip were selected from the white oak trees falling in genuine form class 0.70. The ten ratios are as follows: 0. 98, 0.88, 0.94, 0.98, 0.89, 0.91, 0.97, 0.88, 0.88 and 0.90, with the average at 0.921. This average is the result of averaging according to A of statement (13) on page 291. Within the range of diameters found in the white oak data, hypothetical diameters were assumed such that each pair of diameters would satisfy each of the foregoing ratios. An expression follows which gives the ratio of the average diameters. The first pair of diameters, one in the numerator and one in the denominator, when divided, gives the first ratio in the preceding list. The same thing is true for the remaining pairs of diameters:

$$\frac{\dfrac{6.0+13.1+5.8+4.9+12.8+5.1+6.4+10.1+11.1+8.1}{10}}{\dfrac{6.1+14.9+6.2+5.0+14.4+5.6+6.6+11.5+12.6+9.0}{10}}=\frac{8.34}{9.19}=0.908.$$

It is seen that the average ratio determined in this manner conforms to the procedure given in B of statement (13) on page 291. The average diameter at seven tenths of the distance from the tip is 8.34 inches, and the average diameter at the base is 9.19 inches. The average ratios by the two procedures are seen to differ by 1.3 per cent. The ratio that was determined by the A process is the one that has been used in the past for comparisons to test the conformity to theoretical curves. In any event, the product of the ratio at the given height times the base diameter should give the average diameter at the given height. Accordingly, 0.921 × 9.19 = 8.46 instead of 8.34, which is the actual average diameter.

The main function of any form curve is to make possible the determination of the volume of a solid of the given form, or the determination of a diameter at any distance from the tip. In either case an approximation to the diameter at any point on the curve enter into consideration. So far as the ratio read from the curve fails to picture the average ratio that will correctly reproduce the average diameter, to that extent is the curve in error. If the average that is used as a norm by which the adequacy of the curved value is determined will not itself reproduce the average diameter at any given point when the basal diameter is known, then no assurance regarding the adequacy of the curve values is possible.

It must not be thought that a great error is usually made by this procedure in determining the adequacy of curve values. Especially is this true in the case of a species that has a regular taper. When, however, the stem taper is extremely variable from tree to tree, care should be taken to investigate the error that is introduced by using the average of a set of ratios instead of the ratio of averages. In studying the influence of various factors on tree form, some investigators have concerned themselves about the possibility of this or that small deviation of the average of ratios being significant. It is entirely possible that these small deviations may be the result of the difference between the average of the ratios and the ratio of the average diameters. Therefore, the curve value might easily be absolutely correct, or the error might be in the opposite direction, and the deviation be twice the amount that their results indicate.

It is easily seen that the amount of computational labor is materially lessened when the ratio of the average diameters is used. At a specific height, the sum of the diameters of all trees falling in a given form class may be divided by the sum of all the diameters at breast height. In this manner the ten average ratios for a given form class may be calculated by only ten divisions. By the method of the average of ratios ten divisions must be made to determine the ratios for each tree. Though this may easily be done on the slide rule, the chances of error and the additional effort are certainly worth consideration.

In order to determine the variation in the average ratios for white oak, that resulted from the use of the two methods of procedure, the ratios at each tenth of height for each tree in the data were averaged by genuine form classes. Also, the upper diameters at each tenth of height were averaged by genuine form classes. For each genuine form class the average diameter at each tenth of the stem's height was divided by the average diameter at eight tenths from the tip, and a series of ratios of averages was thus constructed. The results are presented in Table II.

From a comparison of the A and B series of Table II it is apparent that very real differences between the series do exist. Genuine form classes 0.60, 0.65 and 0.70 show pronounced variations. In these genuine form classes the variations are not compensating, nor does either method of computation give consistently higher results. It must be pointed out that in certain instances variations of 1 per cent between the A and B series may be due to the fact that in one series the ratio may have been slightly over an even multiple of five-thousandths, and in the other series somewhat under an even multiple of five-thousandths. Consequently, in rounding off the ratio to two significant figures, the apparent deviation is greater than the actual deviation. This is not true, however, in all instances in which variation occurred. The magnitude of the variation depends largely upon the distribution of the variates about the mean for any point of measurement on the stem. This distribution will vary with any set of data that may be collected.

It will be seen from Table II that, for the most part, ratios are given to two significant figures. Since tree diameters are

TABLE II

Comparison between the Average of Ratios and the Ratio of Average Diameters

Genuine form class	Series	Percentage of distance from tip to breast height										Basis no. of trees
		100	90	80	70	60	50	40	30	20	10	
		Average ratios inside bark										
.40	A*	1.20	1.07	1.00	.91	.79	.60	.40	.28	.19	.09	12
.40	B	1.20	1.06	1.00	.92	.80	.59	.41	.28	.18	.08	12
.45	A	1.16	1.05	1.00	.92	.79	.62	.45	.33	.22	.11	13
.45	B	1.16	1.05	1.00	.92	.79	.63	.46	.33	.21	.11	13
.50	A	1.18	1.07	1.00	.93	.83	.67	.50	.38	.26	.13	32
.50	B	1.19	1.06	1.00	.94	.83	.68	.51	.38	.25	.13	32
.55	A	1.19	1.07	1.00	.93	.83	.69	.55	.40	.27	.13	74
.55	B	1.19	1.07	1.00	.93	.83	.69	.56	.40	.26	.12	74
.60	A	1.20	1.08	1.00	.93	.85	.75	.60	.45	.30	.16	71
.60	B	1.22	1.08	1.00	.94	.86	.75	.62	.46	.31	.15	71
.65	A	1.20	1.08	1.00	.93	.85	.76	.65	.49	.33	.17	70
.65	B	1.18	1.07	1.00	.92	.85	.75	.64	.48	.31	.16	70
.70	A	1.19	1.08	1.00	.93	.87	.80	.70	.53	.35	.18	54
.70	B	1.18	1.06	1.00	.93	.87	.79	.69	.52	.34	.18	54
.75	A	1.22	1.08	1.00	.94	.88	.83	.74	.55	.36	.17	18
.75	B	1.22	1.08	1.00	.94	.87	.82	.74	.55	.35	.17	18
.80	A	1.25	1.08	1.00	.96	.88	.85	.79	.62	.38	.18	6
.80	B	1.24	1.06	1.00	.96	.89	.85	.80	.63	.38	.18	6
.85	A and B	1.26	1.09	1.00	.95	.92	.87	.83	.61	.38	.17	1

* A = average of ratios; B = ratio of average diameters.

read to tenths of inches, and most of the upper diameters were less than ten inches, two significant figures in the diameters of the higher portion of the stem are all that the data justify.

A question may be raised concerning the reason for not leveling the data that appear in Table II, in order that the increase in diameter ratios in any column may progress in a regular manner from the lowest to the highest form class. The leveling might also have been accomplished by making the diminution of diameter ratios along any line progress regularly. Leveling in both directions should have done much to iron out incidental variations. This leveling was not done, because the taper curves were desired in a form such that the goodness of their fit to the data could be discovered by a computation of the standard deviation of the diameter ratios at a given height from the mean diameter ratio at that height. This could not have been done if leveled curves had been used.

FORM GROUPING

A conception of the adequacy of grouping the trees into form classes on the basis of the ratio between the diameters at

TABLE III

Standard Deviations of Diameter Ratios at Given Tenths of the Distance from Tip to Breast Height

Genuine form class	Percentage of distance from tip to breast height										Basis no. of trees
	100	90	80	70	60	50	40	30	20	10	
	Standard deviations										
.40	.072	.027	.00	.047	.085	.066	.013	.036	.046	.024	12
.45	.037	.026	.00	.051	057	.037	.012	.035	.045	038	13
.50	.067	.043	.00	.040	069	049	.014	.038	047	.037	32
.55	.068	.035	.00	.036	.062	054	.013	.042	051	.040	74
.60	.059	.037	.00	.033	.045	038	.016	.042	.043	.036	71
.65	.084	.035	.00	.029	.042	.038	.014	.035	.051	.042	70
.70	.070	.035	.00	.033	.039	.033	014	.063	.068	.056	54
.75	.063	.033	.00	.029	.022	.028	.015	.062	.053	.035	18
.80	.069	.055	.00	.013	024	.028	.009	.046	.051	.033	6
											350

four tenths and eight tenths of the distance from the tip is obtained by grouping the data by this method and calculating the standard deviation from the mean of the diameter ratios at each tenth of the stem's height. The standard deviations at various distances from the tip are given in Table III.

From these data it is apparent that the variation resulting from a deviation of one standard unit from the mean ratio for any form class at any given height is relatively large. For purposes of comparison the following table of standard deviations of white pine (*Pinus Strobus* L.) is taken from the work of Gevorkiantz and Hosley (5, p. 35). Although the authors do not definitely define the significance of the tabulated values, it is inferred from the context that they represent the standard deviations of the diameter ratios at each tenth of the stem's height about the mean ratio for each form class.

TABLE IV

STANDARD DEVIATIONS OF WHITE PINE DIAMETER RATIOS

Distance from tip to breast height, as a percentage	Standard deviation from mean of form class. Average for all form classes
.90	± 2.8
.80	± 2.9
.70	± 2.9
.60	± 2.5
.50	.....
.40	± 2.2
.30	± 3.2
.20	± 3.3
.10	± 3.0

In order to compare the standard deviations in Table IV with those in Table III, divide the standard deviations in Table IV by 100. This comparison shows white oak to have greater variability of stem form than does the white pine with which Gevorkiantz and Hosley worked.

A comparison of the curves of numbers of white oak trees shows that many of them have a point at which there is a decided break in the trend of the curve. The possibility of classifying trees into form classes on the basis of the percentage of height above breast height at which this break occurs has been investigated. The deviations of the ratios from the average ratio at the various heights are shown in Table V.

TABLE V

STANDARD DEVIATION OF ERRORS FROM MEAN RATIO AT GIVEN TENTHS OF DISTANCE FROM TIP TO BREAST HEIGHT

Breaking-point Classification

Breaking-point class tenths of height	Percentage of distance from tip to breast height			Basis no. of trees
	100	60	20	
	Standard deviation of errors *			
Z	.077	.050	.060	144
3	.056	.073	.055	24
4	.066	.040	.067	51
5	.062	.042	.070	63
6	.073	.044	.057	50
7	.044	.035	.093	16
				348

* In order to shorten a very long computation, the standard deviations at 100, 60 and 20 per cent from the tip were the only ones calculated.

Class Z includes those trees whose curves showed no definite breaking point. Classes 3, 4, . . ., contain trees whose curves had a definite break at 3, 4, . . ., tenths of the height above breast height. One tree fell in Class 2 and two trees fell in Class 8. These were not included in Table V, since the standard deviations would have little significance.

Comparison of Tables III and V shows no superiority of the breaking-point system of classification over the genuine form-class method. Had the standard deviations at four tenths from the tip been compared, the genuine form-class method would have been superior to the breaking-point classification. The basis upon which grouping into genuine form classes is done makes this result inevitable. By the genuine form-class system, trees are grouped into classes on the basis of the diameter ratio at four tenths from the tip, and the maximum dispersion of ratios about their mean at this height is 0.02. This will give a small standard deviation at this point, whereas the breaking-point classification may be expected to have a much greater dispersion about the mean at four tenths from the tip. It is apparent from Tables III and V that by neither method of classification can white oak be grouped into classes that show consistent form.

STEM FORM OF WHITE OAK

From the preceding paragraph the genuine form-class grouping is seen to be preferable to the breaking-point system of classification. Is there any significant trend in the form variation from one genuine form class to another? Figure 8 presents graphically the B-values from Table II. From this figure it is apparent that

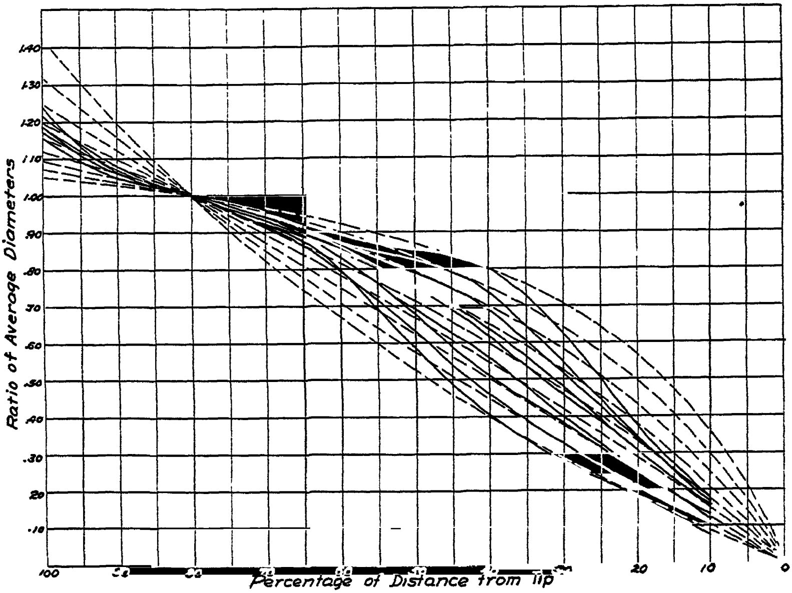

FIG. 8. Comparison of empirical curves of white oak and theoretical curves of Behre's formula: - - - curves of Behre's formula; —— white oak curves

TABLE VI

RINIKER GENUINE FORM FACTORS FOR DIFFERENT FORM CLASSES

Genuine form class	Series A	Series B	Basis no. of trees
.40	.50	.49	12
.45	.51	.51	13
.50	.53	.53	32
.55	.54	.54	74
.60	.57	.57	71
.65	.58	.57	70
.70	.60	.59	54
.75	.62	.61	18
.80	.65	.65	6
.85	.65	.65	1
			351

below seven tenths from the tip there is a striking agreement among all genuine form classes. Above this point the form-class curves are well defined. Since the curves vary only in the upper portion, is the variation sufficient to warrant the use of a system of form classification? To determine this, the average diameter ratios for the whole mass of data were found for eight, nine and ten tenths from the tip. These averages were used for all genuine form classes below eight tenths from the tip. By this procedure the A and B values in columns headed 100 and 90 in Table II are as follows for all genuine form classes.

	100	90
A	1.20	1.08
B	1.20	1.07

With these values for the lower two tenths of the stem's height and the values from Table II at the other heights, Riniker's genuine form factors were computed by Simpson's rule [20] for each form class for both the A and B series.

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[20] Simpson's rule is expressed as follows:

$$f = \frac{\Delta x}{3}\left[y_0^2 + y_{10}^2 + 4\,(y_1^2 + y_3^2 + \ldots + y_9^2) + 2\,(y_2^2 + y_4^2 + \ldots + y_8^2)\right]$$

where y is expressed as a diameter ratio, taken from Table II, and f is the Riniker genuine form factor.

TABLE VII

DEVIATION * OF RATIOS OF AVERAGE DIAMETERS FROM DIAMETER RATIOS READ FROM BEHRE'S CURVE

Genuine form class	Percentage of distance from tip to breast height										Basis no. of trees
	100	90	80	70	60	50	40	30	20	10	
	Difference between ratios of average diameters inside bark and diameter ratios read from Behre's curve										
.40	−.23	−.14	00	+.10	+.13	+.06	+.01	−.01	00	− 01	12
.45	−.16	−.11	00	+.07	+.08	+.05	+.01	00	00	+.01	13
.50	−.06	−.06	00	+.06	+.08	+.06	+.01	00	00	+.01	32
.55	−.01	−.03	00	+.03	+.04	+.02	+.01	−.02	−.03	−.03	74
.60	+.07	00	00	+.03	+.04	+.04	+.02	−.01	−.02	−.03	71
.65	+.06	+.01	00	−.01	00	−.01	−.01	−.05	−.07	−.05	70
.70	+.09	+.01	00	−.01	−.01	−.01	−.01	−.06	−.10	−.07	54
.75	+.15	+.04	00	−.02	−.03	−.01	−.01	−.09	−.15	−.13	18
.80	+.19	+.03	00	−.01	−.03	−.02	00	−.08	−.19	−.18	6
											350

* Curve is taken as normal; deviations are plus or minus from the curve.

In the Riniker genuine form factor the variation between certain intermediate genuine form classes is very slight, although the form deviation from the lowest to highest genuine form class is a considerable one.

An attempt has been made to determine whether or not a set of curves, such as Behre's, can reproduce in any satisfactory manner the data actually measured. Table VII shows for each genuine form class the difference between the measurements on white oak and the diameter ratios from Behre's curve.

The diameter ratios from Behre's curve for genuine form classes 0.55, 0.60 and 0.65 fit the observed data rather well. In the lower portions of the stem the lower genuine form classes have a negative deviation and the higher genuine form classes a positive one. This fact, as well as the curves in Figure 8, points to the conclusion that all genuine form classes have a similar form in the lower stem portions. In the upper stem portions practically all deviations are negative, but in the lower genuine form classes the deviations are slight.

TABLE VIII

INFLUENCE OF HEIGHT UPON TAPER WITHIN GIVEN GENUINE FORM CLASS

Height class * in feet	Average diameter breast-high in inches	Percentage of distance from tip to breast height										Basis no. of trees
		100	90	80	70	60	50	40	30	20	10	
		Ratios of average diameters inside bark Genuine form class .55										
20	3.6	1.17	1.08	1.00	.92	.77	.66	.55	.38	.28	.17	2
30	4.3	1.20	1.06	1.00	.94	.82	.68	.54	.43	.31	.15	5
40	6.6	1.16	1.07	1.00	.92	.80	.67	.55	.42	.27	.14	16
50	9.2	1.20	1.07	1.00	.93	.84	.70	.55	.39	.26	.13	29
60	12.7	1.23	1.07	1.00	.94	.85	.72	.56	.40	.25	.12	11
70	13.3	1.21	1.08	1.00	.96	.84	.65	.56	.44	.29	.14	4
80	14.5	1.19	1.09	1.00	.93	.87	.74	.56	.40	.26	.13	7
												74
		Genuine form class .60										
20	3.6	1.18	1.06	1.00	.92	.86	.76	.59	.41	.29	.15	3
30	3.8	1.23	1.12	1.00	.93	.87	.77	.60	.45	.31	.17	7
40	6.4	1.19	1.07	1.00	.93	.84	.73	.60	.46	.31	.16	11
50	8.6	1.20	1.08	1.00	.93	.85	.75	.60	.44	.29	.15	25
60	9.0	1.20	1.07	1.00	.93	.85	.76	.61	.47	.32	.17	11
70	13.8	1.21	1.06	1.00	.92	.85	.73	.60	.44	.30	.15	8
80	14.0	1.22	1.09	1.00	.94	.86	.75	.62	.47	.29	.13	6
												71

* The twenty-foot height class includes trees ranging in height from 19.6 feet to 29.5 feet. Other height classes follow similarly.

TABLE VIII (*continued*)

Influence of Height upon Taper within Given Genuine Form Class

Height class * in feet	Average diameter breast-high in inches	Percentage of distance from tip to breast height										Basis no. of trees
		100	90	80	70	60	50	40	30	20	10	
		Ratios of average diameters inside bark Genuine form class .65										
20	3.6	1.22	1.10	1.00	.92	.86	.78	.66	.50	.34	.20	2
30	3.6	1.20	1.07	1.00	.93	.84	.73	.64	.52	.37	.19	7
40	6.6	1.18	1.08	1.00	.92	.85	.77	.66	.49	.32	.16	16
50	7.8	1.20	1.07	1.00	.93	.85	.77	.65	.49	.32	.16	25
60	8.8	1.22	1.08	1.00	.93	.86	.76	.64	.48	.34	.18	11
70	11.9	1.17	1.07	1.00	.88	.85	.82	.65	.44	.28	.13	2
80	15.4	1.19	1.07	1.00	.94	.86	.78	.66	.47	.29	.14	5
90	14.0	1.19	1.10	1.00	.93	.87	.76	.65	.50	.30	.13	2
												70

* The twenty-foot height class includes trees ranging in height from 19.6 feet to 29.5 feet. Other height classes follow similarly.

It may be thought that the wide variations in Table VII are due principally to large individual variations arising from irregular branching in the tree crowns. A summary similar to Table VII has been prepared for those trees whose stem curve showed no definite breaking point. In this summary the deviations are consistently smaller than the deviations in Table VII, but the tendencies for variation are similar; the only exception is a greater number of positive deviations in the upper portions of stems of low genuine form class.

Figure 8 presents graphically Table VII. The diameter ratios from Behre's curves are shown in broken lines, one line for each genuine form class, whereas the ratios of average diameters for the white oak data are shown in solid lines. The numerical designation of the curve representing any form class can be determined by reading the ordinate of the curve at 40 per cent of the distance from the tip. At this abscissa Behre's curve for form class 0.50 has an ordinate of 0.50, etc. The empirical curves for the white oak data very nearly agree with the theoretical curves at this abscissa. It is plainly seen, however, that the curves of Behre's equation do not represent the stem form of white oak.

THE EFFECT OF CERTAIN FACTORS UPON TAPER

The influence of height upon form of white oak has been studied from two viewpoints. The influence of height upon trees falling within the same genuine form classes is seen from the results that are tabulated in Table VIII. For the purpose of this comparison three of the stronger genuine form classes are presented. Table VIII shows that no consistent tendency for variation is associated with height within any given genuine form class.

The influence of height on the ratios of average diameters at the various tenths of the stem's height has been studied independently of genuine form class, and the results are presented in Table IX. For this tabulation all the sample trees were divided into ten-foot height classes, and the ratios of average diameters at the several tenths were calculated for the height classes included within the data.

TABLE IX

RATIOS OF AVERAGE DIAMETERS INSIDE BARK FOR WHITE OAK SORTED ACCORDING TO HEIGHT

Height class* in feet	Percentage of distance from tip to breast height										Basis no. of trees
	100	90	80	70	60	50	40	30	20	10	
	Ratios of average diameters inside bark										
20	1.18	1.07	1.00	.92	.83	.71	.56	.42	.31	17	14
30	1.21	1.09	1.00	.92	.82	.71	.58	.46	.32	.17	30
40	1.18	1.07	1.00	.92	.82	.71	.59	.44	.29	.15	69
50	1.19	1.07	1.00	.93	.85	.73	.59	.43	.28	.14	125
60	1.21	1.07	1.00	.93	.85	.75	.62	.46	.31	.16	53
70	1.21	1.07	1.00	.93	.85	.71	.58	.43	.28	.14	19
80	1.20	1.08	1.00	.93	.86	.77	.64	.48	.30	.14	30
90	1.20	1.07	1.00	.95	.88	.80	.71	.52	.32	.15	11
											351

* The twenty-foot height class includes trees ranging in height from 19.6 feet to 29.5 feet. Other height classes follow similarly.

From this tabulation a slight tendency toward a fuller form in the larger height classes is apparent. More particularly is this true of the ratio of average diameters at three tenths to seven tenths from the tip.

The influence of the ratio between crown length and total height of tree upon the taper throughout the stem's length was investigated for white oak by separating those trees upon which crown-length measurements were available into ratio classes where the ratios fell into ten-unit classes varying between 0.196 and 0.295, etc. Table X presents the ratios between the average diameters at various heights for the different crown-ratio classes.

It appears from this tabulation that trees with long crowns have a slightly greater amount of taper in the upper portion of the stem than do trees with short crowns.

The influence of crown class on the taper of white oak trees is shown in Table XI.

TABLE X

RATIOS OF AVERAGE DIAMETERS FOR WHITE OAK, SORTED ACCORDING TO RATIO OF CROWN LENGTH TO TOTAL LENGTH

Ratio between crown length and total length	Percentage of distance from tip to breast height										Basis no. of trees
	100	90	80	70	60	50	40	30	20	10	
	Ratios of average diameters inside bark										
.20	1.14	1.03	1.00	.89	.77	.70	.59	.44	.30	.15	1
.30	1.18	1.07	1.00	.91	.83	.75	.63	.49	.34	.18	15
.40	1.17	1.06	1.00	.93	.86	.75	.60	.43	.28	.14	35
.50	1.20	1.07	1.00	.94	.85	.71	.55	.39	.25	.12	44
.60	1.18	1.06	1.00	.92	.83	.70	.55	.39	.25	.12	25
.70	1.18	1.09	1.00	.88	.72	.57	.45	.34	.21	.11	2
											122

TABLE XI

RATIOS OF AVERAGE DIAMETERS FOR WHITE OAK, SORTED ACCORDING TO CROWN CLASSES

Crown class	Percentage of distance from tip to breast height										Basis no. of trees
	100	90	80	70	60	50	40	30	20	10	
	Ratios of average diameters inside bark										
Dominant . . .	1.17	1.06	1.00	.92	.83	.72	.57	.41	.26	.13	16
Codominant .	1.20	1.07	1.00	.93	.85	.72	.56	.39	.25	.12	37
Intermediate .	1.18	1.07	1.00	.93	.85	.73	.58	.43	.29	.14	62
Oppressed (Suppressed) .	1.13	1.03	1.00	.91	.75	.63	.52	.40	.27	.13	3
											118 *

* Trees measured in southwestern Connecticut.

The conclusion drawn from these data is that form variation is independent of crown class in white oak, although the sample in the oppressed class is too small to give more than an indication relative to the conditions in that class.

When the white oak data are sorted into age classes, and the ratio of the average diameters at the various heights computed and averaged, the results are as shown in Table XII. Age apparently has no influence whatsoever on the taper of white oak.

TABLE XII

RATIOS OF AVERAGE DIAMETERS FOR WHITE OAK,
SORTED ACCORDING TO AGE

Age * in years	Percentage of distance from tip to breast height										Basis no. of trees
	100	90	80	70	60	50	40	30	20	10	
	Ratios of average diameters inside bark										
20	1.17	1.07	1.00	.94	.84	.71	.57	.43	.30	.17	6
30	1.23	1.09	1.00	.92	.84	.73	.61	.46	.31	.16	41
40	1.20	1.08	1.00	.93	.85	.75	.62	.47	.32	.17	36
50	1.20	1.08	1.00	.94	.86	.75	.61	.45	.30	.15	56
60	1.18	1.07	1.00	.93	.84	.71	.57	.42	.28	.14	87
70	1.19	1.07	1.00	.93	.85	.75	.61	.45	.31	.15	45
80	1.19	1.07	1.00	.89	.80	.68	.52	.38	.25	.12	9
90	1.23	1.05	1.00	.90	.82	.72	.57	.41	.26	.12	5
130	1.21	1.05	1.00	.98	.89	.71	.55	.40	.27	.14	1
150	1.20	1.05	1.00	.95	.87	.72	.66	.48	.27	.12	1
160	1.23	1.05	1.00	.99	.93	.69	.60	.55	.36	.16	1
											288

* The twenty-year age class embraces trees whose ages vary from 20 to 29 years, inclusive.

Table XIII shows no significant relationship between diameter at breast height and the ratios of average diameters at various heights on the stem of the tree.

TABLE XIII

RATIOS OF AVERAGE DIAMETERS FOR WHITE OAK, SORTED ACCORDING TO DIAMETER AT BREAST HEIGHT

Diameter breast-high in inches*	Percentage of distance from tip to breast height										Basis no. of trees
	100	90	80	70	60	50	40	30	20	10	
	Ratios of average diameters inside bark										
3	1.17	1.07	1.00	.92	.82	.71	.59	.47	.33	.18	22
4	1.21	1.09	1.00	.92	.82	.70	.55	.41	.29	.16	19
5	1.18	1.08	1.00	.91	.83	.72	.62	.47	.32	.17	22
6	1.19	1.10	1.00	.92	.82	.73	.61	.48	.32	.16	23
7	1.20	1.08	1.00	.93	.85	.75	.63	.48	.32	.17	46
8	1.19	1.07	1.00	.94	.86	.75	.62	.47	.31	.16	63
9	1.20	1.07	1.00	.94	.84	.73	.59	.44	.30	.15	40
10	1.19	1.07	1.00	.94	.86	.74	.59	.42	.27	.13	25
11	1.17	1.07	1.00	.92	.84	.72	.55	.39	.26	.13	24
12	1.17	1.06	1.00	.91	.82	.72	.59	.42	.28	.14	9
13	1.24	1.08	1.00	.92	.84	.73	.60	.43	.28	.14	14
14	1.21	1.06	1.00	.95	.86	.74	.60	.44	.26	.13	13
15	1.19	1.07	1.00	.93	.87	.78	.66	.53	.31	.13	9
16	1.21	1.07	1.00	.92	.85	.74	.62	.46	.27	.12	10
17	1.21	1.07	1.00	.96	.87	.79	.65	.44	.29	.15	7
18	1.19	1.08	1.00	.93	.90	.77	.66	.54	.33	.13	3
19	1.23	1.06	1.00	.94	.87	.73	.58	.42	.29	.15	2
											351

* The three-inch diameter class embraces trees whose diameters vary from 2.6 to 3.5 inches, inclusive.

From the preceding tabulations it appears that the taper of white oak is not correlated with crown class, age or diameter at breast height, and is but slightly influenced by height and crown length.

The influence of distribution upon form is an important consideration for the forester, since the tables of wood volume for any species depend upon the similarity of form of trees grown in the several parts of the commercial range of the species. Table XIV indicates that the form of white oak in southeastern Ohio is very similar to that grown in eastern West Virginia. The ratios of average diameters of the New York trees are markedly lower at 30, 40 and 50 per cent of the distance from the tip than are the West Virginia and Ohio trees. Connecticut trees conform very well to the Ohio and West Virginia trees for the lower half of the stem, but are considerably smaller in the upper half. Since variations in the upper portion of the stem affect the volume a relatively smaller amount than equivalent variations in the lower portion, the form factor is affected no more than is shown in column 2 of Table XIV.

TABLE XIV

RATIOS OF AVERAGE DIAMETERS FOR WHITE OAK, SORTED ACCORDING TO LOCALITY

Locality	Riniker genuine form factor	Percentage of distance from tip to breast height										Basis no. of trees
		100	90	80	70	60	50	40	30	20	10	
		Ratios of average diameters inside bark										
Connecticut...	.55	1.19	1.07	1.00	.93	.84	.72	.57	.41	.27	.13	122
New York....	.56	1.20	1.09	1.00	.92	.82	.71	.58	.45	.31	.17	72
West Virginia.	.58	1.20	1.07	1.00	.94	.86	.76	.64	.48	.30	.15	55
Ohio.........	.58	1.21	1.08	1.00	.93	.86	.75	.63	.48	.32	.16	95
												344

ROOT SWELL

Since the common practices for eliminating root swell[21] cannot be satisfactorily applied to the irregularly tapering stem of white oak, a conception of the amount of root swell present has been determined by diameter classes. Average diameters inside bark at each tenth of the stem's height were determined for all trees falling in each diameter class. A series of curves was made in which height was plotted on the horizontal and average diameter inside bark on the vertical scales. Since most of the diameter classes contained a sufficient number of trees to give significant averages,[22] a set of relatively smooth curves resulted. In all cases root swell was apparent. To determine the amount of this distortion, the smooth upper portion of the curve was prolonged downward, and the amount of swelling read from the graph. From Figure 9 the amounts of root swell at breast height were read, and are presented in Table XV.

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[21] See page 290.

TABLE XV

AMOUNT OF ROOT SWELL AT BREAST HEIGHT

Diameter class * in inches	Root swell in inches	Basis no. of trees
3	0.25	22
4	0.35	19
5	0.20	22
6	0.30	23
7	0.45	46
8	0.60	63
9	0.70	40
10	0.85	25
11	0.30	24
12	0.37	9
13	1.05	14
14	1.30	13
15	1.10	9
16	1.20	10
17	1.42	7
		346

* The four-inch diameter class embraces trees whose diameters at breast height outside bark vary from 3.6 inches to 4.5 inches, inclusive.

Figure 9 indicates that an appreciable amount of root swell may frequently be expected to reach a height of one tenth of the stem's length above breast height, although it is doubtful whether the swell reaches as high as two tenths in any considerable number of trees.

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[22] In Figure 9 the diameter-height curves for the 16- and 17-inch trees have not been continued to the tip. Insufficiency of data in these diameter classes caused irregularities in the upper portions. However, the smooth lower portion gives a satisfactory conception of the amount of root swell.

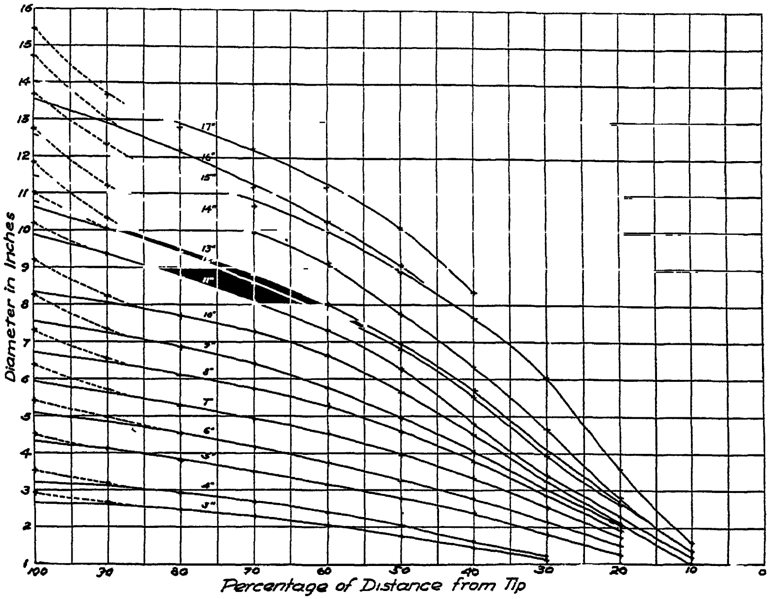

FIG. 9. Root swell as shown by diameter-height curves. - - - departure of the actual diameter curve from the normal curve of the upper stem when it is prolonged downward to breast height

BARK DEVELOPMENT

Investigations into bark thickness have been carried on by several investigators on several species, with varying results. Mattsson (16, p. 883) finds that in European larch (*Larix europaea* DC.) the bark thickness expressed as a percentage of the diameter of the wood is a minimum in the middle portion of the tree stem. At this point the bark forms 10–15 per cent of the diameter of the wood. For the lower stem portion the bark percentage increases to 15–20 per cent, and Mattsson states that toward the tip the bark percentage approaches infinity.[23]

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[23] Since there is a ratio at the tip determined by the differentiation of embryonic tissue at the growing tip, it is obvious that this statement is not literally true. It would be clarified by changing "infinity" to "that ratio initially determined by primary differentiation."

Jonson (10, p. 305), working with Scotch pine, finds that the bark in percentage of diameter inside bark at the various heights on the tree stem is thinnest near the middle of the stem's height. Toward either end this percentage increases, but is greater at breast height than it is at one tenth the distance from the tip to breast height.

Pemberton's investigations (20, p. 46) on redwood (*Sequoia sempervirens* Endl.) indicate that the ratio between bark thickness and diameter[24] decreases from the base to the tip of the tree. He also concludes that the bark-diameter ratio is practically constant at breast height for any diameter of trees.

Hedeby (7, p. 212) shows graphically that the bark percentage is greatest near the tip of Swedish oak. Lower on the stem the bark percentage gradually decreases, and is a minimum at the base of the tree. His researches also show that the bark percentage at breast height is greatest for the lower diameter classes, and diminishes gradually as the diameter at breast height increases.

Investigations of Gevorkiantz and Hosley (5, p. 38) on white pine bark in central New England indicate that the relationship between bark and total diameter is about the same at breast height as it is at one tenth the distance from the tip to breast height. From either end the bark percentage gradually approaches a minimum at the center of the tree.

The white oak data, as presented in Table XVI, confirm the findings of Hedeby (7, p. 212).

It is seen that the bark percentage at breast height diminishes more or less regularly from the lower to the higher diameter classes. Since the greater part of the irregularity is found in the higher diameter classes where the data are weakest, at least a part of the irregularity may be attributed to this weakness. Further irregularity is possibly due to the distribution of the size classes throughout the several localities in which the data were gathered. It is seen from Table I (p. 289) that several of the diameter classes are represented by sample trees from a

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[24] In the absence of a direct statement, the inference is that this diameter is diameter on bark.

TABLE XVI

DOUBLE-BARK THICKNESS DIVIDED BY DIAMETER ON BARK AT GIVEN TENTHS FROM TIP TO BREAST HEIGHT

Diameter breast high * in inches	Percentage of distance from tip to breast height										Basis no. of trees
	100	90	80	70	60	50	40	30	20	10	
	Double-bark thickness divided by diameter on bark										
3	.11	.12	.12	.12	.12	.13	.13	.13	.14	.15	22
4	.11	.12	.12	.12	.12	.11	.13	.14	.15	.17	19
5	.11	.11	.12	.12	.12	.13	.14	.15	.17	.19	22
6	.11	.10	.11	.11	.12	.12	.12	.14	.15	.17	23
7	.099	.096	.098	.10	.10	.11	.12	.13	.15	.17	46
8	.092	.096	.10	.11	.11	.12	.12	.14	.15	.17	63
9	.091	.097	.10	.11	.11	.12	.13	.14	.15	.17	40
10	.090	.093	.099	.10	.11	.12	.12	.14	.15	.18	25
11	.084	.088	.091	.098	.10	.11	.12	.14	.16	.17	24
12	.087	.088	.094	.10	.11	.12	.13	.14	.15	.16	9
13	.084	.092	.091	.092	.095	.099	.10	.13	.14	.16	14
14	.089	.093	.092	.091	.092	.10	.11	.12	.15	.16	13
15	.087	.087	.088	.084	.083	.083	.085	.090	.12	.15	9
16	.080	.086	.085	.084	.085	.091	.10	.11	.14	.15	10
17	.088	.10	.10	.098	.094	.095	.10	.12	.15	.17	7
											346

* The four-inch diameter class embraces trees whose diameters vary from 3.6 inches to 4.5 inches, inclusive.

single locality. It may be that trees of the same diameter at breast height will exhibit different bark thicknesses in different parts of the range of the species. In order to determine whether this supposition was tenable, trees from the four localities that furnished the greater part of the data were sorted on diameter at breast height, and the bark percentage at breast height for diameter classes was calculated by localities. No diameter class was represented in all the localities, but where diameter classes were found in more than one locality there was not universal agreement in bark percentage. In three diameter classes there were significant averages obtainable in two localities, and in these there was close agreement in bark percentage. When the averages in one locality were based on a small number of trees, disagreement in bark percentage was common. It is impossible to say definitely whether the variation is due to inadequate data or to regional variation, although it is the author's personal feeling that the latter possibility is of considerable importance.

This belief is strengthened by the manner in which the actual bark thickness in inches varies from one diameter class to another. In Table XVII the double-bark thickness was calculated by multiplying the bark percentage at breast height, taken from Table XVI, by the actual average diameter at breast height for each diameter class.

TABLE XVII

BARK THICKNESS IN INCHES FOR GIVEN DIAMETER CLASSES

Diameter class in inches	Bark thickness in inches	Basis no. of trees
3	0.36	22
4	0.44	19
5	0.56	22
6	0.67	23
7	0.70	46
8	0.74	63
9	0.83	40
10	0.91	25
11	0.93	24
12	1.04	9
13	1.08	14
14	1.25	13
15	1.31	9
16	1.28	10
17	1.49	7
		346

It is observed that the break in the regular trend of the bark increase at the seven-inch diameter class coincides with the increasing influence of the Ohio trees and the diminishing influence of the New York trees.[25] Irregularity in the higher diameter classes cannot be attributed with definiteness to this cause, since in no locality are strong averages found.

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[25] See Table I, page 289.

Within any diameter class the bark percentage increases from breast height to the tip, and the bark percentage at the tip appears to be approximately constant for all diameter classes. In the greater number of diameter classes the rate of increase in bark percentage is relatively slow in the lower part of the stem, and rises sharply at about four tenths of the distance from the tip to breast height.

This diminishing in bark percentage from the tip to the base of white oak trees is very easily accounted for. Near the tip of the stem all the bark elements formed by the cambium and cork cambium are present. Casual observation on a few white oak sections having two or three annual rings shows that at this age the thickness of bark is about one fifth to one third of the radius of xylem tissue. As the bark ages it forms into ridges that are susceptible to scaling off by animals and the bending action of the wind. Natural weathering also disintegrates the exposed bark portions. Consequently, not all the bark formed by the tree is present in the lower portions of the stem, and the radius of the xylem cylinder does not diminish. This causes a reduction in the bark percentage at any given point on the stem as the age of the stem at that point increases.

Büsgen and Münch (2, p. 144) explain the variation in bark percentage in pine[26] in the following manner: "The raggedness of the surface of bark is caused by the stretching of the rind associated with the growth in thickness of the stem of the tree. The cork cambium and the other living constituents of the rind follow it by cell multiplication, cell growth and the formation of larger intercellular spaces, so that these parts of the rind behave like a coat which enlarges of its own accord with the growth of the wearer. The dead bark cannot do this and therefore acquires fissures whose direction generally follows the length of the stem and depends in individual cases on the constitution of the bark. . . . In the pine the shedding of the scales in the upper part of the stem occurs early and in thin layers, while further down the scales remain on for a long time. Above, therefore, there are always present new, brightly coloured scales, whilst below every scale has time to change colour under the influence of the weather and the impurities that settle upon it."

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[26] Presumably Büsgen and Münch here refer to Scotch pine.

In conclusion, it appears that bark percentage at given stem heights varies from species to species according to the peculiarities of bark structure that are characteristic of the different species.

FORM CLASS DETERMINATION

Many investigators have expressed themselves concerning the best method for the determination of form class. Jonson (11, p. 244) has developed the form-point method, which has been successfully used in Sweden. Behre (1, p. 741) reports its successful use on western yellow pine in Idaho. Wright (31, p. 81) finds approximately the same correlation between the height of the center of crown length and form quotient which he finds between form point and form quotient. Gevorkiantz and Hosley (5, p. 24) have found that by means of an equation involving the relative length of crown free from live branches and crown index [27] the form quotient for white pine can be computed with a considerable degree of accuracy. Nyblom (19, p. 57) states that the form class seems to be comparatively independent of the relative length of crown, except for the extreme form classes. Heijbel (8, p. 141), working with Scotch pine, finds that in all form classes the crown ratio varies within the limits given for the entire stand, and evidently is quite independent of the form quotient. Mattsson (17, p. 228) concludes that in fully stocked stands of Scotch pine the form class increases with age. Accordingly, a table giving the average form class at various ages for stands of given densities should prove useful in form-class determination. Schumacher (27, p. 197) can find no significant correlation in second-growth redwood between form quotient and diameter breast-high, or age or site. He does, however, find a strong relationship between form quotient and the height within a given diameter class, and suggests this as a possible means of obtaining the form class.

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[27] "Crown index" is an expression of the relationship between the diameter of crown and diameter of stem at breast height.

In view of this mass of conflicting evidence, an attempt was made to correlate relative crown length and form quotient. Measurements on crown length were available for 121 trees from Connecticut. The relative crown length was calculated for each of the 121 trees by dividing the crown length by the total height of the tree. The correlation between this ratio and the genuine form quotient is − 0.40 ± 0.05, and the standard deviation of prediction, when predicting genuine form quotient from crown ratio, is ± 0.076.[28] Figure 10 shows the straight line that expresses the relationship between form quotient and the ratio of crown length to total height.[29] It is apparent from Figure 10 and the standard deviation of prediction that crown length has a certain amount of influence upon the genuine form quotient, but not enough to use as a predicting agent in determining the form quotient for a single tree.

In the investigation of the simultaneous influence of crown length and crown width upon genuine form quotient, an equation involving these as independent variables was determined. In this instance the crown width was expressed as a ratio between the diameter of the crown in feet and the diameter of the tree in feet. The equation thus determined is

$$Q = 0.72 - 0.39x_1 + 0.0022x_2. \tag{14}$$

In this equation Q is the genuine form quotient, x_1 is the ratio between the crown length and total height, and x_2 is the ratio between crown width and diameter at breast height. When this formula is used the standard deviation of the error in predicting the form quotient is 0.077.

An attempt was made to improve this equation by the inclusion of a third independent variable, height. The resulting equation is of the form

$$Q = 0.61 - 0.40x_1 + .0030x_2 + .0019x_3, \tag{15}$$

---

[28] This standard deviation of prediction was calculated from the formula $\sigma_e = \sigma_y \sqrt{1 - r^2}$.

[29] The equation of this line was calculated by the relationship $y = r\frac{\sigma_y}{\sigma_x}x$. Here y is the deviation from the mean form quotient and x is the deviation from the mean ratio between crown length and total height.

where Q, x_1, x_2 are as in equation (14), and x_3 is the total height of the tree in feet. The standard deviation of error in predicting form quotient when this formula is used is 0.076. The addition of height as an independent variable does not appreciably increase the accuracy of the predicting equation.

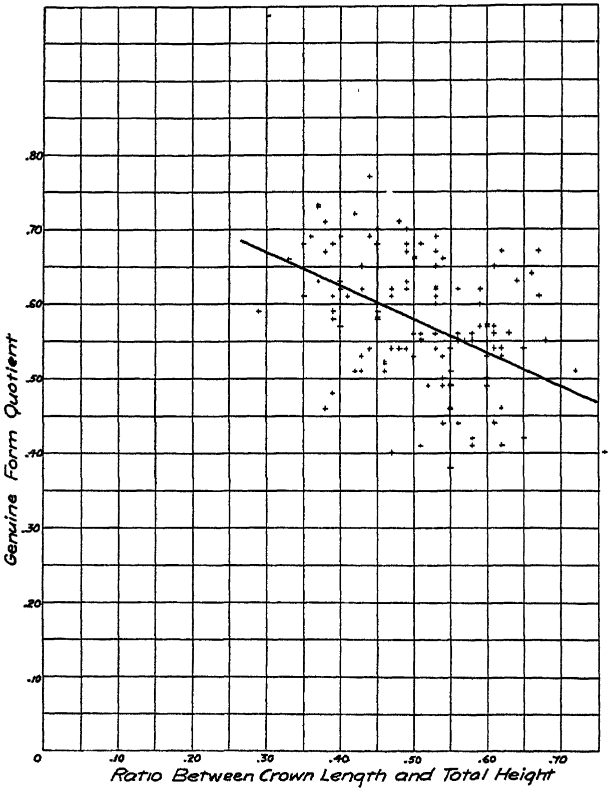

FIG. 10. Relation between relative crown length and genuine form quotient.

Equation of line is

$$Y = -0.45X + 0.80$$

Y = genuine form quotient

X = relative crown length

The standard deviations of the two equations and the correlation coefficient show that the more complicated formulae are no more accurate instruments for the prediction of the form quotient than is the ratio between crown length and total height of tree. The smallness of the coefficients of the x_2 and x_3 terms in equations (14) and (15) supports this statement. This analysis indicates that the approximate genuine form quotient can be predicted when only the ratio between crown length and total height of the tree is known, and that in 68 per cent of such predictions the error in the predicted genuine form quotient will not be greater than 0.076. Since genuine form classes comprise, in this study, five form class units, such a predicted form quotient may be expected to be in error by an entire genuine form class in more than 50 per cent of the cases.

The work of Petrini (22, p. 606) on Norway spruce in Sweden shows a standard deviation of 5.40 form class units[30] when computing form class by means of the form point. This standard deviation is based on a sample of 104 trees. He also finds (22, p. 614) the correlation coefficient between form point and form quotient to be 0.351 ± 0.058. The white oak data do not show so small a standard deviation of errors of prediction as spruce data do.

Common practice has assumed that within any stand the mean form class of the stand pictures with a relative amount of accuracy the form class of the stand. Since the standard deviation of the mean varies inversely as the square root of the number of observations, the accuracy of form class determination of a stand can be increased by increasing the number of trees upon which the average form class is based.

If one assumes the average form class of the stand to be obtainable to a reasonable degree of accuracy, there remains the variability of form of white oak as shown in Table III (p. 298). In addition to this variability there is the further consideration that the span of genuine form classes from 0.50 to 0.70 inclusive, embracing 85 per cent of the total number of trees, shows a difference of only six or seven hundredths in form factor. This means that the average variation in volume from one form class to the adjacent form class above or below is about 2 per cent. When one considers jointly the slight variation in form factor and the high standard deviation of the ratios from which the form factors were computed, form class classification is not justified for white oak.

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[30] Multiply Petrini's standard deviation by 0.01 for purposes of comparison with the standard deviations given on pages 319 and 321.

SUMMARY

In many instances the method of using the average of ratios will give the same results as the ratio of average diameters. However, before conclusions in studies of comparative form are drawn, care must be taken that the small form variations that may be thought to be significant are not, in reality, due to the method of securing the average ratios.

The genuine form quotient can be used to separate white oak trees into genuine form classes, but the variation of stem form from tree to tree within any genuine form class is large. The breaking-point system of classification is no more a satisfactory criterion of form than is the genuine form quotient.

In the lowest three tenths of the stem of white oak taper appears to be practically independent of genuine form class. This may be due in part to the effect of root swell, and in part to the effect of the base of crown on the stem form.

The equation of Behre does not represent the form of white oak.

Form variation appears to be independent of crown class, age and diameter at breast height. There is a tendency toward fuller form in the larger height classes, and also in the shorter-crowned trees.

Geographic distribution seems to affect the stem form slightly, but from this study it is doubtful whether such variation will affect materially the volume determination of tree stems.

Root swell is present at breast height on trees as small as the three-inch diameter class, and for larger diameter classes the amount of swelling increases. It is doubtful whether appreciable swelling reaches two tenths of the stem's height above breast height, but it frequently reaches one tenth of the height.

The bark percentage increases from breast height to the tip in trees of all diameter classes, and the breast-height bark percentage decreases with an increase in diameter class.

The genuine form-class system of classifying trees for more accurate volume determinations is not thought to be suitable or practicable for white oak, because of (1) the difficulty of accurately and simply determining the genuine form class, (2) the variability of taper on individual trees within any genuine form class, and (3) the slight variation in form factor that is found from genuine form class to genuine form class.

CONCLUSION

In an estimate of the wood volume on an area comprising a number of thousands of acres the error introduced by form variation should be smaller than a similar estimate on a small area. Table VI on page 302 indicates that the span of average form factors for various form classes is about 0.16. This means that the volumes of the lowest and highest form classes differ by about 16 per cent. The use of a single-volume table, constructed to fit the average form of these data, will be expected to introduce an error considerably smaller than 16 per cent. For estimation of volumes on larger tracts this degree of accuracy may be all that can be expected. For research purposes, however, where accurate volume determinations on small areas are required, this amount of error is large. Where the number of trees per plot is small, variations above and below the average are less likely to be compensating than they are in stands of thousands of trees. In consequence, accurate volume averages can be obtained only by giving attention to the individual tree stem. This can be done by estimating diameters at given heights on every tree on the sample area. From these measurements tree volumes in any desired unit of measurement can be determined with the use of appropriate tables. This procedure will involve an increase in the cost of this type of forest research which foresters at the present time may not be prepared to meet. When the need for greater accuracy in volume determination becomes sufficiently acute, precise methods of determination will of necessity be adopted.

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APPENDIX A

The development of formula (4), page 278, is taken from Müller (18, pp. 13 and 203).

The rotation of the curve $y^2 = px^r$ about the x-axis will generate a solid whose longitudinal section may be represented as in Figure 11.

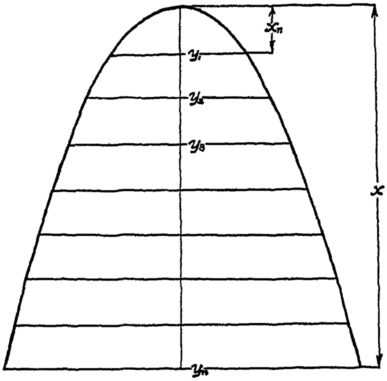

FIG. 11. Graph of parabolic curve

If x is divided into n equal units and at each unit distance from the tip a radius $y_1 \ . \ . \ . \ y_n$ is laid off

$$
\begin{aligned}
y_1^2 &= p\left(\frac{1}{n}x\right)^r \\
y_2^2 &= p\left(\frac{2}{n}x\right)^r \\
y_3^2 &= p\left(\frac{3}{n}x\right)^r \\
&\vdots \\
y_n^2 &= p\left(\frac{n}{n}x\right)^r .
\end{aligned}
$$

By proportion

$$\frac{y_1^2}{y_n^2} = \frac{p\left(\frac{1}{n}x\right)^r}{p\left(\frac{n}{n}x\right)^r} = \frac{1^r}{n^r}$$

$$\frac{y_2^2}{y_n^2} = \frac{2^r}{n^r}$$

$$\begin{matrix} \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \end{matrix}$$

$$\frac{y_n^2}{y_n^2} = \frac{n^r}{n^r}.$$

Transposing the denominator of the left member, we have

$$y_1^2 = \left(\frac{1}{n}\right)^r y_n^2$$

$$y_2^2 = \left(\frac{2}{n}\right)^r y_n^2$$

$$\begin{matrix} \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \end{matrix}$$

$$y_n^2 = \left(\frac{n}{n}\right)^r y_n^2.$$

If one considers y as a radius of a cylinder of height $\frac{x}{n}$, the volume, z, of the cylinder is

$$z_1 = y_1^2\pi\frac{x}{n} = \left(\frac{1}{n}\right)^r y_n^2\pi\frac{x}{n} = \frac{1^r}{n^{r+1}}y_n^2\pi x$$

$$z_2 = y_2^2\pi\frac{x}{n} = \left(\frac{2}{n}\right)^r y_n^2\pi\frac{x}{n} = \frac{2^r}{n^{r+1}}y_n^2\pi x$$

$$\begin{matrix} \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \end{matrix}$$

$$z_n = y_n^2\pi\frac{x}{n} = \left(\frac{n}{n}\right)^r y_n^2\pi\frac{x}{n} = \frac{n^r}{n^{r+1}}y_n^2\pi x.$$

The sum of these cylinders is

$$\Sigma z = \frac{1}{n^{r+1}} y_n^2 \pi x [1^r + 2^r + 3^r + \ldots + n^r].$$

The bracketed term is an arithmetic series of the r^{th} order whose sum

$$S_n = \frac{n^{r+1}}{r+1} + \frac{n^r}{f_1} + \frac{n^{r-1}}{f_2} + \ldots + \frac{n^2}{f_y} + \frac{n}{f_x},$$

wherein the expressions f_1, f_2, etc., do not need to be evaluated, since they later drop from consideration as n goes to infinity. Placing the sum formula in the brackets and multipying by $\frac{1}{n^{r+1}}$, we obtain

$$\Sigma z = y_n^2 \pi x \left[\frac{n^{r+1}}{n^{r+1}(r+1)} + \frac{n^r}{n^{r+1} f_1} + \frac{n^{r-1}}{n^{r+1} f_2} + \ldots + \frac{n}{n^{r+1} f_x} \right]$$

$$\Sigma z = y_n^2 \pi x \left[\frac{1}{r+1} + \frac{1}{n f_1} + \frac{1}{n^2 f_2} + \ldots + \frac{1}{n^r f_x} \right].$$

When n approaches infinity and $\frac{x}{n}$ approaches 0

$$\frac{1}{n f_1} = \frac{1}{n^2 f_2} = \frac{1}{n^r f_x} = 0,$$

and the volume of the rotation solid is

$$V = \frac{1}{r+1} y_n^2 \pi x.$$[31]

If we substitute for the radius y the base diameter d_o, and for x the length, l, the equation gives the volume

$$V = \frac{1}{r+1} \cdot \frac{\pi}{4} d_o^2 l.$$

In forest problems the d_o is not usually measured at the base of the tree, but at some distance a above it.

$$\left(\frac{d_o}{2}\right)^2 = pl^r \qquad \left(\frac{d_a}{2}\right)^2 = p(l-a)^r.$$

---

[31] This formula can be derived very easily by methods of calculus. Presumably Müller wished to make the derivation clear to students unfamiliar with calculus.

By division

$$\frac{d_o^2}{d_a^2} = \left(\frac{l}{l - a}\right)^r$$

and

$$d_o^2 = d_a^2\left(\frac{l}{l - a}\right)^r.$$

Substituting the value above for d_o^2 the equation for volume becomes

$$V = \frac{1}{r + 1} \cdot \frac{\pi}{4} d_a^2 \left(\frac{l}{l - a}\right)^r l.$$

Since the form factor is the ratio between the volume of a tree and the volume of a cylinder having the same base diameter and height, it is expressed

$$f = \frac{\frac{1}{r + 1} \cdot \frac{\pi}{4} d_a^2 \left(\frac{l}{l - a}\right)^r l}{\frac{\pi}{4} d_a^2 l}$$

$$f = \frac{1}{r + 1}\left(\frac{l}{l - a}\right)^r.$$

APPENDIX B

This example of the calculation of the constants for Höjer's equation for form class 0.70 is translated directly from Jonson's work (9, p. 300).

If we substitute in Höjer's equation

$$\frac{d}{D} = C \log \frac{c + l}{c},$$

known values for d, D and l, we obtain two new equations

$$\frac{70}{100} = C \log \frac{c + 50}{c}$$

and

$$\frac{100}{100} = C \log \frac{c + 100}{c}.$$

If we divide the upper equation by the lower, C is eliminated, and the result can be reduced to

$$0.70 \log (c + 100) = \log (c + 50) + (0.70 - 1) \log c.$$

From this equation c cannot be directly calculated, but by a trial and error process the value, $c = 19.78$, is found to satisfy the equation. If we substitute this value of c into the lower of the first two equations we obtain

$$\frac{100}{100} = C \log \frac{19.78 + 100}{19.78},$$

from which C is found to equal 1.28.

By the substitution of these known values of C and c and any measured value of D, one can calculate the diameter d at any desired height for all trees occurring in form class 0.70. This statement is made on the assumption that the species in question tapers in conformity with the curve of Höjer's equation.

APPENDIX C

The following is taken from Petterson's work (24, p. 39). The equation $y = \log x$ can be shown to be equivalent to Höjer's equation as given on page 278. In the equation $y = \log x$, as it is applied to tree stems, y is the ratio between any diameter and the base diameter, and x is the distance from the tree tip.

The total height of the tree can be represented by x_b.

$$\frac{d}{D} = \frac{\log x}{\log x_b} = \log x \frac{1}{\log x_b}. \tag{a}$$

If we let

$$\frac{1}{\log x_b} = C$$

$$\frac{d}{D} = C \log x. \tag{x}$$

In any coördinate system the abscissa of a point on the x-axis is the distance of that point from the origin expressed in some unit.

Assume that the unit of measurement in Figure 6, page 283, is a meters, and that a given point x on the stem lies z meters from the tip. The distance of the point from the origin is $(a + z)$ meters, or $\frac{a + z}{a}$ measuring units. Therefore, the abscissa

$$x = 1 + \frac{z}{a}.$$

Let us assume that z is l per cent of the tree's absolute length L and that a is c per cent of L. Therefore,

$$\frac{z}{a} = \frac{l}{c}.$$

If we substitute this in

$$x = 1 + \frac{z}{a} = 1 + \frac{l}{c} = \frac{c + l}{c}.$$

Substituting this value of x in equation (x) above we get

$$\frac{d}{D} = C \log \frac{c + l}{c},$$

which is Höjer's equation.

In equation (a) C equals $\frac{1}{\log x_b}$ and x_b is the base abscissa, which in Jonson's application of Höjer's equation is $\frac{c + 100}{c}$. Therefore,

$$C = \frac{1}{\log \frac{c + 100}{c}}.$$

From the relation $x_b = \frac{c + 100}{c}$ may be obtained the value for c:

$$c = \frac{100}{x_b - 1}.$$

With the help of this relationship for c Petterson calculated c for six form classes, namely, 0.55 to 0.80. In order to accomplish this he successively laid the tree's base at the points $x = 1.1, 1.2, 1.3,$ etc., to the value $x = 5.0$, and thereafter at the points $x = 6, 7, 8,$ etc., to the value $x = 30$. The middle diameter corresponding to each value of x_b lies at the point $\frac{x_b + 1}{2}$. For each investigated value of x_b the form class was determined according to equation (a) by dividing $\log$[32] $\frac{x_b + 1}{2}$ by $\log x_b$.

These form classes were plotted as ordinates over the x_b values as abscissae, and a curve was passed through the resulting points. From this curve the value of x_b that corresponds to each form class may be read off. The values of x_b corresponding to form classes 0.55, 0.60, etc., to form class 0.80 were determined and tabulated.

If the diameter at one tenth of the distance from the tip to breast height for form class 0.70 is desired, the procedure is as follows: From the tabulated values of x_b form class 0.70 is seen to have an x_b of 6.056. The tree's length above breast height is $6.056 - 1.0 = 5.056$ measuring units. One tenth of this length is 0.5056 measuring unit, and the desired diameter lies at the point $x = (1 + 0.5056)$. Therefore, $\log x = \log 1.5056$, which equals 0.17771. $\text{Log } x_b = \log 6.056 = 0.78219$. Therefore, the diameter at one tenth from the tip is $\frac{0.17771}{0.78219} = 0.227$ of the breast-high diameter. Other diameters for the several form classes may be computed similarly.

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[32] The log before this term was omitted in Petterson's text, but this must have been a typographical error.

APPENDIX D

Heijbel (8, p. 144) begins the development of his tangent equation with the simple form

$$x = \tan y. \tag{b}$$

In order to eliminate ambiguity he considers the portion of the curve lying between $y = \pm 90°$. The curve has a point of inflection at the origin and is symmetric in the first and third quadrants. From Figure 12 it is seen that x represents the diameter quotient $\frac{d_n}{D}$ and y represents the height quotient $\frac{h_n}{H}$.

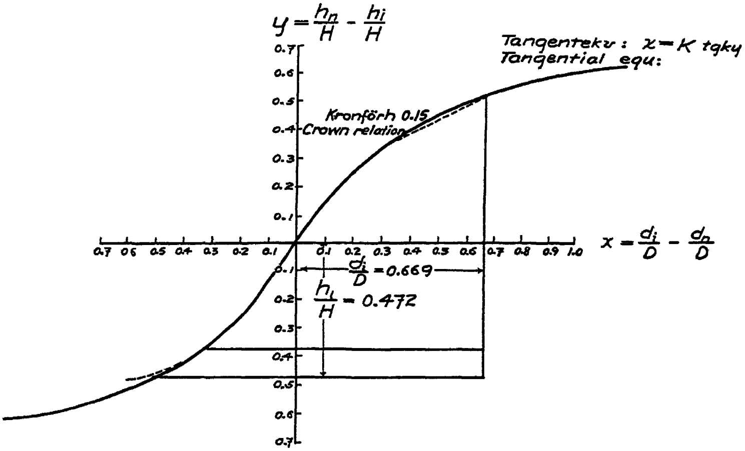

FIG. 12. Curve of Heijbel's equation. Taken from Heijbel

Since the inflection point lies at the origin, the y values read on the curve give the difference between the height quotient and the height quotient of the point of inflection $\frac{h_i}{H}$,

$$y = \frac{h_n}{H} - \frac{h_i}{H}.$$

Similarly, the x value gives the difference between the diameter quotient of the inflection point and the real diameter quotient:

$$x = \frac{d_i}{D} - \frac{d_n}{D}.$$

Equation (b) may then be written

$$\frac{d_n}{D} = \frac{d_i}{D} - \tan\left[\frac{h_n}{H} - \frac{h_i}{H}\right]. \tag{c}$$

In order to make possible the regulation of the necessary conditions in the x and y members, two constants, K and k, are introduced. The equation then reads

$$\frac{d_n}{D} = \frac{d_i}{D} - K\tan\left[k\left(\frac{h_n}{H} - \frac{h_i}{H}\right)\right]. \tag{d}$$

In this equation d_n is the diameter at any height h_n, d_i is the diameter at the point of inflection, and h_i is its height. D is the diameter at ten per cent of the height, and H is the total height of the tree. K and k are constants that vary with the form class and relative crown length. All heights are reckoned from the stump.

Within the crown portion of the stem the actual diameter ratios of trees deviate in a negative direction from the curve of equation (d). Heijbel likens this deviation to the difference between a second-degree and a third-degree parabola, thus,

$$\begin{aligned} y &= ax^2 \\ y_1 &= x^3 \\ y - y_1 &= ax^2 - x^3 = \delta = x^2(a - x). \end{aligned} \tag{e}$$

In this equation δ denotes the difference between the two parabolas. The symbol x corresponds to the height quotient,[33] reckoned from the base of the crown, at which point the two curves are tangent to each other. The point of tangency is indicated by h_a, and is given in percentage of the height of the tree. Accordingly $\frac{h_a}{H}$ is the beginning of the crown. The symbol a is a constant that gives the scale of the y coördinate for the parabola of the second degree when the corresponding scale for the parabola of the third degree is unity. For the reduction of the differences the constant C is introduced. By employing the symbols used in the preceding equation

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[33] It is realized that Heijbel allows x to represent height in one equation and diameter in another, but since this material is almost a literal translation, the author's symbols are retained.

$$\delta = C\left(\frac{h_n}{H} - \frac{h_a}{H}\right)^2 \left[a - \left(\frac{h_n}{H} - \frac{h_a}{H}\right)\right]. \tag{f}$$

In this equation a has the special property not only of denoting the magnitude of the scale in the parabola of second degree, but also the value of the x coördinate at the intersection point of the two curves. In the tree this represents the relative length of crown, or crown ratio.

It can easily be shown from equation (f) that a is equal to the crown ratio. At the tip the two curves coincide and δ is zero. In this case $\frac{h_n}{H} - \frac{h_a}{H}$ is equal to the crown ratio B. If we assume δ to be 0 in equation (f)

$$0 = a - \left(\frac{h_n}{H} - \frac{h_a}{H}\right).$$

But

$$B = \frac{h_n}{H} - \frac{h_a}{H}.$$

Therefore $$a = B.$$

Since the total height of the tree is 1, the crown ratio can be obtained from the base of the crown by means of the following identity: $B = 1 - \frac{h_a}{H} = a$. Equation (f) may then be written

$$\delta = C\left(\frac{h_n}{H} - \frac{h_a}{H}\right)^2 \left(1 - \frac{h_a}{H} - \frac{h_n}{H} + \frac{h_a}{H}\right)$$

$$\delta = C\left(\frac{h_n}{H} - \frac{h_a}{H}\right)^2 \left(1 - \frac{h_n}{H}\right). \tag{g}$$

C is a constant for any given crown ratio, and seems to be unaffected by the form class and crown class of the main curve.

The stem portion from the stump to ten per cent of the height is represented by a power curve of the form

$$y = r(x)^{\frac{1}{3}} \tag{h}$$

Here y is the diameter quotient and x the height quotient. The diameter quotient of the stump diameter, $\frac{d_o}{D}$, corresponds to a height quotient of zero, and the base diameter, D, is measured at ten per cent of the tree's height above the stump. After substituting the symbols previously used for the other equations, equation (h) may be written

$$\frac{d_o}{D} - \frac{d_n}{D} = r\left(\frac{h_n}{H}\right)^{\frac{1}{3}},$$

or

$$\frac{d_n}{D} = \frac{d_o}{D} - r\left(\frac{h_n}{H}\right)^{\frac{1}{3}}. \tag{i}$$

The symbol r may be determined by appropriate computations, and from equation (i) diameter quotients for points lying between the stump and ten per cent of the tree's height may be calculated.

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Med. Förs. = Meddelanden från Statens Skogsförsöksanstalt, Stockholm.

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RESULTS OF THINNING IN WHITE PINE *

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IN 1904 two stands of white pine were planted on old fields in the Saginaw Forest of the University of Michigan, one with a spacing of three feet by three feet and the other four and one-half by four and one-half. In the fall of 1915 the stand planted 3 × 3 was made the basis of a thinning experiment, in which the Danish system of thinning was used and all neutral and injurious secondary trees were removed. These plots were not measured until the fall of 1916. In the fall of 1920 this plot was thinned again and a similar experiment was started in the stand with the four-and-one-half-foot spacing. The thinning in this second stand was Grade C on the basis of Kraft's crown classification. Both plots were thinned again in 1925 and 1930. All trees on the thinned plots and the unthinned controls were measured at the time of each thinning, except as noted above.

This report is concerned primarily with the results of the 1930 thinnings, though the figures for the entire duration of the experiment are given in order to show more clearly the differences in development of the various plots and to include some items that had to be omitted in the first report (4).

There is great need for a more standardized practice in reporting the results of thinnings, in order to compare the results obtained by different investigators. Owing to the variety of forms used by various authors, with the omission of many basic data and a frequent failure to indicate the methods of calculation employed, such comparisons are practically impossible at the present time. This condition, if it continues, will constitute a serious obstacle in the development of an improved thinning practice. Obviously, such a standardization should be extended to

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the collection of the field data obtained from thinning experiments. The form used by Hawley (2) is the most comprehensive and satisfactory one to date, and is the one followed in this report.

In the following tables the plots in the 3 × 3 stand are designated as 2*b*, thinned, and 2*b*, control; those in the 4½ × 4½ stand as 2*c*, thinned, and 2*c*, control.

TABLE I

COMPARISON OF PLOTS AT START OF EXPERIMENT

Plot no.	Age in years	No. trees per acre	Av. diam. in inches	Av. height in feet	Basal area per acre square feet	Vol. per acre cubic feet	Mean annual growth per acre cubic feet
2b, thinned	13	4539	2.0	15.5	105.15	1304	100.3
2b, control	13	3904	2.1	15.8	90.89	1149	88.4
2c, thinned	17	1952	3.3	21.3	117.40	1500	88.2
2c, control	17	1924	3.4	23.0	120.30	1660	97.6

It is evident that there was not anything like a close correspondence between the two plots in Lot 2*b* in the items of number of trees, volume and basal area. The average height of dominant trees in 1930 indicated that the site quality of 2*b*, thinned, is somewhat higher than that of 2*b*, control.

The plots in Lot 2*c* checked rather closely in number of trees per acre, but showed considerable variation in volume and basal area, with the higher values on the control plot. These indications of a slightly higher site quality on the control plot are supported by a larger average height of the dominant trees on that plot.

The following tables show the changes that have occurred on the different plots since thinning was started.

TABLE II

NUMBER OF TREES PER ACRE

Line no.	Time	Plot number			
		2b		2c	
		Thinned	Control	Thinned	Control
		Number of trees per acre			
1	1915 before thinning	4539	3904	....	....
2	1915 after thinning	3946	3904	...	....
3	1920 before thinning	3407	3376	1952	1924
4	1920 after thinning	2044	3376	1434	1924
5	1925 before thinning	2044	2555	1391	1517
6	1925 after thinning	1265	2555	1018	1517
7	1930 before thinning	1261	1878	1018	1151
8	1930 after thinning	1122	1878	937	1151
9	Total loss	3417	2026	1015	773
10	Total loss in per cent	75.2	51.8	51.9	40.1

TABLE III

BASAL AREA PER ACRE

Line no.	Time	Plot number			
		2b		2c	
		Thinned	Control	Thinned	Control
		Basal area per acre in square feet			
11	1915 before thinning	105.15	......	......	......
12	1916 after thinning	95.07	90.89	......	......
13	1920 before thinning	142.63	138.30	117.40	120.30
14	1920 after thinning	111.06	138.30	104.80	120.30
15	1925 before thinning	173.20	178.00	153.46	162.31
16	1925 after thinning	136.63	178.00	130.69	162.31
17	1930 before thinning	178.84	195.60	177.12	181.35
18	1930 after thinning	170.15	195.60	169.37	181.35

TABLE IV

VOLUME PER ACRE IN CUBIC FEET

Line no.	Time	Plot number			
		2b		2c	
		Thinned	Control	Thinned	Control
		Volume per acre in cubic feet			
19	1915 before thinning	1304	....	....	....
20	1916 after thinning	1199	1149	....	....
21	1920 before thinning	1848	1776	1500	1660
22	1920 after thinning	1563	1776	1429	1660
23	1925 before thinning	2812	2801	2612	2790
24	1925 after thinning	2417	2801	2347	2790
25	1930 before thinning	3819	3867	3829	3981
26	1930 after thinning	3669	3867	3685	3981

TABLE V

PERIODIC ANNUAL HEIGHT GROWTH IN FEET

Line no.	Period	Plot number			
		2b		2c	
		Thinned	Control	Thinned	Control
		Periodic annual height growth			
27	1917–30	1.4	1.25	....	....
28	1921–30	....	....	1.44	1.39
29	1917–20	1.27	1.22	....	....
30	1921–25	1.12	1.06	1.46	1.28
31	1926–30	1.30	1.16	1.30	1.36

TABLE VI

Periodic Annual Basal Area Growth in Square Feet

Line no.	Period	Plot number			
		2b		2c	
		Thinned	Control	Thinned	Control
		Periodic annual basal area growth			
32	1917–30	9.31	9.50	.....	....
33	1921–30	.....	.....	9.09	8.62
34	1917–20	12.72	12.88	.....	.....
35	1921–25	12.40	10.70	10.02	10.27
36	1926–30	8.44	7.70	9.29	7.60

TABLE VII

Periodic Annual Volume Growth in Cubic Feet

Line no.	Period	Plot number			
		2b		2c	
		Thinned	Control	Thinned	Control
		Periodic annual volume growth			
37	1917–30	220	212	...	...
38	1921–30	...	...	258	254
39	1917–20	162	163	...	...
40	1921–25	250	220	237	234
41	1926–30	280	254	296	276

The figures in Tables V, VI and VII represent the growth of only those trees that are still alive on the respective plots at the end of each of the given periods. Those in Tables VIII, IX and X are obtained by subtracting the figure for each item at the beginning of the period from the corresponding figure at the end of the period and then dividing the difference by the number of years in the period. The latter method is the one usually employed.

TABLE VIII

PERIODIC ANNUAL HEIGHT GROWTH IN FEET

Line no.	Period	Plot number			
		2b		2c	
		Thinned	Control	Thinned	Control
		Periodic annual height growth			
42	1917–30	1.61	1.39	....	....
43	1921–30	....	....	1.73	1.62
44	1917–20	1.52	1.40	....	....
45	1921–25	1.48	1.34	1.82	1.54
46	1925–30	1.82	1.44	1.64	1.70

TABLE IX

PERIODIC ANNUAL BASAL AREA GROWTH IN SQUARE FEET

Line no.	Period	Plot number			
		2b		2c	
		Thinned	Control	Thinned	Control
		Periodic annual basal area growth			
47	1917–30	5.98	7.48	....	....
48	1921–30	.....	.....	7.23	6.10
49	1917–20	11.89	11.85	....	....
50	1921–25	11.63	7.94	9.73	8.40
51	1925–30	8.44	3.52	9.29	3.81

A comparison of the figures in Tables V, VI and VII with the corresponding ones in Tables VIII, IX and X shows at once the marked differences in results obtained by the two methods

TABLE X

PERIODIC ANNUAL VOLUME GROWTH IN CUBIC FEET

Line no.	Period	Plot number			
		2b		2c	
		Thinned	Control	Thinned	Control
		Periodic annual volume growth			
52	1917–30	187	194	...	...
53	1921–30	...	...	240	232
54	1917–20	162	157	...	...
55	1921–25	250	205	237	226
56	1925–30	280	213	298	238

of calculation and the degree to which such figures obtained in the usual way are misleading. The figures for height growth in Table VIII are all higher than the corresponding ones in Table V. On the other hand, the basal area growth as shown by the figures in Table IX is smaller in every case than the actual growth (Table VI). The effect of calculating volume growth as in Table X is to exaggerate the differences between the thinned plots and their controls, since the figures obtained for growth on the controls are lower than they should be. Lower figures than the true ones are also obtained for the thinned plots during periods in which a considerable number of trees died in addition to those cut.

The erroneous results of the usual form of calculation, when used as a basis for comparing thinned and unthinned areas, were indicated by the writer in the first report upon this experiment (4). The same matter was discussed more fully later by Righter (3). In the following comparisons of thinned and unthinned plots only the true figures (Tables V, VI, VII) are used.

The effect of thinning upon height growth has been practically negligible. The small differences shown could easily have been caused by the differences in site conditions on the several plots.

Basal area growth on 2*b*, thinned, has exceeded that on the control during the last two five-year periods, but the difference during the last period is less than half of that for 1921–25. On the 2*c* plots, the thinned area showed less growth than the control during 1921–25, but revealed a considerable advantage over the control during the last period.

Both thinned plots have a somewhat larger rate of volume growth than their controls during the last two periods, but in neither case is it very great. If the thinned plots are credited with the volumes cut as a part of their growth, as is often done, the effect of thinning in increasing volume growth appears to be considerable. The correctness of this procedure may be questioned, especially in the case of early thinnings. The volumes cut represent only material that is kept from going to waste, as it does on unthinned areas, provided there is a market for it. But in the case of early thinnings, there is often little or no market, so that the trees may be cut and still be wasted just as much as those that die on the unthinned plots. Later, when the thinnings possess merchantable value, the income from them is very properly added to other incomes from the tract, but to include their volumes in calculating mean or periodic annual growth gives a distorted picture of the true growth relationships between thinned and unthinned areas.

The conditions on the plots prior to the 1930 thinning are given in Table XI.

A comparison of the items in Table XI with those in Table I reveals the changes that have occurred since the beginning of thinning operations. On 2*b*, thinned, death and cutting have removed 72.1 per cent of the number of trees, while the loss on the control has been 51.9 per cent. On the 2*c* plots, the losses have been 47.8 per cent on the thinned and 40.2 per cent on the control.

The average diameters of all the trees on the 2*c* plots show a difference of only 0.2 inch in favor of the thinned plot. If it had not been for the thinning, the difference would probably have been the other way, as it is when the average diameters of the dominants and codominants are compared. Of the 2*b* plots the thinned one shows a decided superiority in average diameter both

TABLE XI

CONDITION OF WHITE PINE THINNING PLOTS IN 1930

Plot no.	Age in years	No. trees per acre	Av. diam. in inches		Av. height in feet		Basal area per acre square feet	Vol. per acre cubic feet	Mean annual growth per acre cubic feet
			All trees	Dominants and codominants	All trees	Dominants and codominants			
2b, thinned	27	1261	5.1	5.6	38.1	40.2	178.8	3819	141.4
2b, control	27	1878	4.4	5.1	35.3	38.3	195.6	3867	143.2
2c, thinned	27	1018	5.6	6 1	38.6	40.8	177.1	3829	141.8
2c, control	27	1151	5.4	6.8	39.2	42.4	181.3	3981	147.4

for all trees and for dominants and codominants, though it is less for the latter.

The average heights of dominants and codominants indicate that site quality is nearly the same on the two thinned plots, poorest on the 2*b*, control, and best on the 2*c*, control. According to Frothingham's yield tables for white pine (1), these height figures indicate that all the plots are on Site I.

As regards total basal area, there has been only a slight increase in the superiority of 2*c*, control, over 2*c*, thinned, but 2*b*, control, has changed from an inferior position to one of marked superiority over 2*b*, thinned.

The two thinned plots are surprisingly near together in total volume, though both are below their controls. The 2*c*, control, has been ahead of the thinned plot from the start, but its lead has decreased from 160 cubic feet to 152 cubic feet. In contrast, 2*b*, control, has changed an initial deficiency of 155 cubic feet to a lead of 48 cubic feet.

In the matter of mean annual volume growth for the entire 27 years, all the plots are much closer together than in 1916 and 1920, with the two thinned plots almost the same and both of them below the control plots.

The degree of change in the relative amount of growing space per tree that is produced by thinning operations can be shown

TABLE XII

DISTANCE FACTORS OF WHITE PINE THINNING PLOTS

Line no.	Time	Plot number			
		2b		2c	
		Thinned	Control	Thinned	Control
		Distance factors			
57	1915 before thinning	17.6	....	....	....
58	1916 after thinning	18.8	19.1	....	....
59	1920 before thinning	15 9	15.9	17.2	16.8
60	1920 after thinning	17.3	15 9	17.8	16.8
61	1925 before thinning	14.2	14.2	14.9	14.6
62	1925 after thinning	15 8	14 2	15.9	14.6
63	1930 before thinning	13.8	13.1	13.9	13.5
64	1930 after thinning	14.0	13.1	14.1	13.5

very well by computing the respective distance factors (the ratio of average distance between stems to the average diameter). See Table XII.

Several items of interest appear in the last table. Because of the higher initial density of 2*b*, thinned, the first two thinnings were sufficient to hold the relative density even with that of the control. The 1925 thinning was heavy enough to keep the distance factor of the thinned plot above that of the control up to the 1930 thinning. The distance factor of 2*c*, thinned, has been greater constantly than that of the control, but the difference just before the 1930 thinning was exactly the same as at the beginning. The factors show that the heaviest thinning on both plots was that of 1925 and that the lightest one was in 1930. The 1930 thinning was very light, since it was evident that not enough cleaning was being obtained. Cleaning was considered insufficient because the length of live crown on the dominant trees was well over one third of their total height.

From the data given by Hawley in his report on the white pine thinning plots at Keene (2), the distance factors in Table XIII have been computed.

TABLE XIII

DISTANCE FACTORS OF KEENE WHITE PINE THINNING PLOTS

Line no.	Time	Plot number		
		601 Heavy thinning	602 Light thinning	604 Unthinned
		Distance factors		
65	1905 before thinning	14.5	15.0	14.6
66	1905 after thinning	17.3	17.3	14.6
67	1915 before thinning	15.1	14.8	13.6
68	1915 after thinning	18.8	17.1	13.6
69	1920 before thinning	17.4	16.1	13.4
70	1920 after thinning	18.4	16.4	13.4
71	1925 before thinning	16.4	14.9	12.8
72	1925 after thinning	18.3	16.4	12.8

It will be noted that on both thinned plots the relative density is less than at the beginning of the experiment, whereas on the Saginaw Forest plots it is greater in spite of the thinnings. Therefore, it is safe to conclude that both the thinnings at Keene have been markedly heavier than either of those on the Saginaw Forest. This conclusion is also borne out by an inspection of the volume relations. On Plot 601, the volume prior to the 1925 thinning was only 372.8 cubic feet greater than in 1905, and on Plot 602, 1062.8 cubic feet larger. In contrast, Plot *2b*, thinned, had a volume prior to the 1930 thinning that was 2515 cubic feet larger than in 1916, and Plot *2c*, thinned, showed an increase of 2329 cubic feet since 1920. The Keene thinnings have sacrificed a part of the possible volume of final cut for the sake of more rapid growth on the remaining individual trees. In view of the fact that cleaning on the Saginaw plots has been less than is considered desirable and that the distance factors are considerably smaller than those for the thinned plots at Keene, it would appear that there has also been some sacrifice of cleaning on the latter.

CONCLUSION

1. Thinning of the Saginaw plots has not resulted in a great increase in current volume growth.

2. The increase in current volume growth, credited to thinning, is exaggerated by the method of calculation usually employed.

3. Thinning has been valuable in these stands in the removal of damaged and badly formed trees, thus giving more growing space to better, adjoining trees that would have been injured otherwise.

4. The smaller amount of débris under the thinned stands has resulted in a lower fire hazard.

5. Thinning has caused a small increase in the size of the average tree, a difference which will undoubtedly become larger with increase in age.

6. Thinning has prevented a considerable volume from going to waste.

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NOTES AND STUDIES ON ARACHNIDA. II

ARANEAE FROM THE DOUGLAS LAKE REGION, MICHIGAN. I *

ARTHUR M. CHICKERING

FROM July 10 to July 21, 1930, the author of this paper collected Araneae and other Arachnida in the vicinity of Douglas Lake, Michigan, the site of the Biological Station of the University of Michigan. Very little attention has been given to spiders and their close relatives in this region. It is desirable that we should have as accurate knowledge as possible concerning this group of animals in a region where many other divisions of the biota are being intensively studied. This paper consists of a briefly annotated list of seventy-one species belonging to thirteen families. A few forms in my collection remain undetermined. It is hoped to continue the study of this group during the next few years, with the intention of adding somewhat to the knowledge of their biology. As will be apparent in the following notes, certain species listed in this paper were very abundant at the time of my visit to this region, and evidently constitute a conspicuous part of the fauna. Others, like most of the Attidae, seemed to be rather scarce.

Dr. Paul S. Welch of the University of Michigan has kindly presented me with a small collection of spiders, most of which came from the vicinity of Ann Arbor and Douglas Lake in 1918. Two species from Douglas Lake not found in my collection of 1930 were *Dolomedes triton* (Walckenaer) and *Argiope trifasciata* (Forskål).

Late in the summer of 1930 I spent some time in working over the Douglas Lake collection of spiders at the University of Michigan, where I was extended every courtesy of the Zoölogical Laboratory by Dr. Peter Okkelberg and other members of the staff, to whom I wish to express my gratitude at this time.

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* Contribution from the Biological Laboratory of Albion College and from the Biological Station of the University of Michigan.

The arrangement adopted in this list is that of Petrunkevitch (1928), as published in his *Systema Aranearum.*

SUB-ORDER ARACHNOMORPHAE

AMAUROBIIDAE

Amaurobius bennetti (Blackwall). — Egg-sacs common at this date. Most frequently found under cement bridges and in other similar situations.

AGELENIDAE

Agelena naevia Walckenaer. — Not nearly so common here at the time of my visit as in the southern part of the state.

Coelotes fidelis Banks.

Hahnia agilis Keyserling. — These small spiders spin delicate webs over depressions on the ground. I found the animals most frequently in the boggy parts of the terrain. This may be on account of the greater amount of moisture on the webs, which renders them more easily seen.

PISAURIDAE

Dolomedes triton (Walckenaer). — This specimen is included only in the collection of 1918.

Pisaurina mira (Walckenaer). — This species was found frequently, together with its beautiful nursery-web, along the lake shore where wild-grape leaves were utilized to build the nursery.

LYCOSIDAE

Arctosa cinerea (Fabricius). — Found only on the beach. Nearly all of my specimens are immature.

Lycosa avida Walckenaer.

LYCOSA CAROLINENSIS Walckenaer. — This is the largest spider in this region. Found under boards and other débris around ruined buildings.

LYCOSA FRONDICOLA Emerton.

LYCOSA GULOSA Walckenaer.

LYCOSA SPECIES(?)

PARDOSA EMERTONI Chamberlin.

PARDOSA MILVINA (Hentz).

PARDOSA MOESTA Banks.

PARDOSA XERAMPELINA (Keyserling).

PARDOSA SPECIES(?)

PIRATA ASPIRANS Chamberlin. — There is a little uncertainty in the determination of this species.

PIRATA FEBRICULOSUS (Becker).

SCHIZOCOSA CRASSIPES (Walckenaer).

DICTYNIDAE

DICTYNA SUBLATA (Hentz).

THERIDIIDAE

ENOPLOGNATHA MARMORATA (Hentz).

LITHYPHANTES COROLLATUS (Linnaeus).

STEATODA BOREALIS (Hentz).

THERIDION FRONDEUM Hentz.

THERIDION PUNCTISPARSUM Emerton.

THERIDION SPIRALE Emerton.

THERIDION TEPIDARIORUM C. Koch.

THERIDION ZELOTYPUM Emerton.

LINYPHIIDAE

LINYPHIA COMMUNIS Hentz. — This species has been called the "bowl and doily spider" by Comstock, because of the form of its web. It is one of the most common animals found in the Douglas Lake region. It seems to be almost everywhere among the low bushes and young trees.

LINYPHIA MARGINATA C. Koch. — Comstock has called this species the "filmy dome spider," from the form of its web. It is almost as common as *L. communis*.

LINYPHIA PHRYGIANA C. Koch. — This is also a very common species.

LINYPHIA PUSILLA Sundevall.

ULOBORIDAE

HYPTIOTES CAVATUS (Hentz). — This is the only American species of this genus. Called triangle spider because of the form of its web.

ARGIOPIDAE

ARANEUS CAVATICUS (Keyserling). — One immature specimen seems to belong to this species.

ARANEUS CORNUTUS Clerck. — This spider seems to occur almost everywhere in the region around Douglas Lake. It is the most common species in my collection.

ARANEUS MARMOREUS Clerck. — This very beautiful spider is also very common. Its favorite place for web-building seems to be among the white birches, where its retreat is located within the rolls of bark.

ARANEUS PATAGIATUS Clerck. — Much less common than *A. cornutus*.

ARANEUS THADDEUS (Hentz).

ARGIOPE TRIFASCIATA (Forskål). — This species was not taken in my collection of 1930, but was included in that of 1918.

CYCLOSA CONICA (Pallas). — One of the common species in the bog lands.

EUCTA LACERTA (Walckenaer).

EUSTALA ANASTERA (Walckenaer). — Found only on the southern shore of Douglas Lake. Webs often overhang the water.

LEUCAUGE VENUSTA (Walckenaer). — A very beautiful cosmopolitan species from all states, Central America, West Indies and Colombia; listed by Petrunkevitch.

METEPEIRA LABYRINTHEA (Hentz).

NEOSCONA ARABESCA (Walckenaer). — Probably the most common of all Araneinae, on grasses, flowers and low bushes.

Found in great numbers along certain portions of the shore of Lake Huron near Cheboygan.

SINGA MACULATA Emerton.

SINGA VARIABILIS Emerton.

TETRAGNATHA ELONGATA Walckenaer.

TETRAGNATHA EXTENSA (Linnaeus).

TETRAGNATHA LABORIOSA Hentz.

TETRAGNATHA STRAMINEA (Emerton).

THERIDIOSOMA GEMMOSUM (L. Koch). — Found quite commonly in bog lands making its webs over holes in the ground or at the bases of trees and stumps.

DRASSIDAE

DRASSODES NEGLECTUS (Keyserling).

GNAPHOSA GIGANTEA Keyserling.

HERPYLLUS VASIFER (Walckenaer).

ZELOTES ATER (Hentz).

THOMISIDAE

MISUMENA VATIA (Clerck). — Very common on wild flowers. Notable for its remarkable change of color when moved from white flowers to yellow flowers or vice versa. This has been known since Packard's experiments in 1905, but it has been studied more recently by Gabritschevsky (1927). This investigator has shown that female spiderlings which are white are unable to assume a yellow color on yellow paper. Adult females change to yellow and back to white when changed a second time.

MISUMENOPS ASPERATUS (Hentz).

PHILODROMUS PERNIX Blackwall.

THANATUS COLORADENSIS Keyserling.

TIBELLUS OBLONGUS (Walckenaer). — Next to *M. vatia* this is the most common crab spider in my collection of 1930.

XYSTICUS FEROX (Hentz).

CLUBIONIDAE

CASTANEIRA CINGULATA (C. Koch).

CLUBIONA ABBOTI L. Koch.

CLUBIONA CANADENSIS Emerton.

CLUBIONA OBESA Hentz.

CLUBIONA RIPARIA L. Koch. — This species is common in this region. It builds its nest by folding broad-leaved grasses into three-sided chambers, within which the eggs are deposited.

PHRUROLITHUS ALARIUS (Hentz).

ATTIDAE

DENDRYPHANTES CAPITATUS (Hentz).

PHIDIPPUS CLARUS Keyserling.

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SPERMATOGENESIS IN THE BELOSTOMATIDAE

III. THE CHROMOSOMES IN THE MALE GERM CELLS OF A LETHOCERUS FROM NEW ORLEANS, LOUISIANA *

ARTHUR M. CHICKERING

THE study of the germ cells in the Belostomatidae has been continued for a number of years. During this time particular attention has been devoted to the examination of the male cells of several species. In *Lethocerus americanus* Leidy eight chromosomes are found in the spermatogonia. Six of these are autosomes; two constitute a typical XY-pair of sex-chromosomes. All of the eight chromosomes behave as expected in other similar cases. The autosomes pair and form conspicuous atelomitic ring-tetrads. Three bivalent chromosomes and separate X- and Y-chromosomes appear in all primary spermatocytes. All divide in the first maturation division; the tetrads divide reductionally and the sex-chromosomes equationally. Thus each secondary spermatocyte receives three autosomal dyads and an X- and a Y-chromosome. A very brief union of the sex-chromosomes occurs in the secondary spermatocytes just before the second maturation division. In this division each autosomal dyad divides equationally, and the sex-chromosomes merely separate and thus reduce. In this way each spermatid obtains three autosomes and either an X- or a Y-chromosome.

In an unidentified species of Lethocerus occurring in southern Michigan and collected in the vicinity of Ann Arbor but four chromosomes are regularly found in the spermatogonia. These are large reniform bodies very similar to the autosomes of *L. americanus.* No sex-chromosomes are regularly present in this species. As an aberration, however, small chromosomes closely resembling the XY-pair in *L. americanus* sometimes appear. Two large atelomitic rings occur in the postsynaptic stages, and these seem to show an attachment of a pair of sex-chromosomes to a pair of autosomes. There is also some evidence that the remaining pair of chromosomes is really a double pair, having been formed by the nearly complete union of four different autosomes to make a single tetrad-like body. If this condition actually exists in this species we may suppose that the chromosome complex has been formed by the union of eight chromosomes like those seen in *L. americanus.* A brief description of the process of spermatogenesis in this species is being prepared for publication.

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* While this paper was in press, Dr. H. B. Hungerford, specialist on aquatic Hemiptera, identified my specimens from New Orleans as *Lethocerus uhleri* (Montd.).

The facts cited in the foregoing part of this paper seemed to indicate that the genus Lethocerus may be one in which an interesting series of species exists, characterized by specific chromosomal differences similar to those so frequently described in plants. Moreover, since this genus is difficult for entomologists to separate into species on the basis of somatic differences, some help may be given in this problem by a study of the chromosomal differences. With these possibilities in mind living animals were procured from the vicinity of New Orleans, Louisiana, in the spring of 1928. A dozen animals yielded but two males. The testes of these animals were prepared in the usual way for chromosome study by killing in Bouin's fluid and staining in iron hematoxylin. Ovaries also were prepared for study in a variety of ways and now await examination and comparison with testes.

Samples of this species have been submitted to a specialist for identification, but thus far no decision has been rendered.

The material from the two males from New Orleans has yielded abundant mitoses, from which the following facts have been compiled.

The general topography of the testes in this species is very similar to that found in the two other forms whose tissues have been studied. Although material fixed in Bouin's fluid could not be profitably used for the study of chondriosomes and other cytoplasmic bodies, nevertheless, sufficient remains of these inclusions can be seen to allow some worth-while observations on this material. It is quite evident that both Golgi bodies and chondriosomes are prominent constituents of the cell in this species. Their behavior seems to be essentially the same as that hitherto described for *L. americanus.* However, there may be quite specific differences among these three species in regard to the form of the cytoplasmic inclusions. This seems to be indicated from a study of the chondriosomes in male cells of the species with but four chromosomes where these bodies are conspicuous vesicles, whereas they are granules and rods in *L. americanus.*

Numerous counts of the spermatogonial chromosomes in the species from New Orleans seem to show a rather constant number of twenty-eight, two of which are very small (Fig. 3). This number is unsatisfactory, since thirty is the expected number based upon the later appearance and behavior of the chromosomes of the spermatocytes. The two missing chromosomes should be small bodies similar to those shown. It is conjectured that these minute chromosomes are either attached to or crowded against two other autosomes so as to be obscured from view. Provisionally, the spermatogonial number of chromosomes is placed at thirty.

During diakinesis tetrads become conspicuous, but these are totally different from the large atelomitic rings seen so clearly in the other two species of Lethocerus with the smaller number of chromosomes. No tendency to form ring-tetrads has been observed in this species. The tetrads much more closely resemble the irregular type seen in Benacus (Chickering, 1927). It seems possible that the chromosome complex of *L. americanus* is the basic type, and that the four-chromosome type has been derived from it by union, while the numerous chromosomes of the species from New Orleans have been produced by fragmentation (Figs. 1–3).

All primary spermatocytes appear to contain sixteen chromosomes arranged in the equatorial plate as shown in Figure 4. The sex-chromosomes can be quite positively identified at this time in contact with each other near the center of the group. All chromosomes divide in this division, including the sex-chromosomes and the two minute autosomes. Thus each secondary spermatocyte receives sixteen chromosomes.

The period of interkinesis is very short, and the chromosomes are quickly arranged on the second spindle for the second division. Polar and lateral views of the second spindle show the chromosomes arranged in ringlike formation, with the sex-chromosomes in the center forming a linear dyad, as observed in all of the Belostomatidae thus far examined (Figs. 6–7). Twelve chromosomes usually constitute the ring, with two just outside and the XY-pair within (Fig. 6). The two sex-chromosomes separate from each other before the autosomes divide (Fig. 7). All autosomes appear to divide and thus each spermatid receives fifteen chromosomes, including either an X- or a Y-chromosome (Fig. 8).

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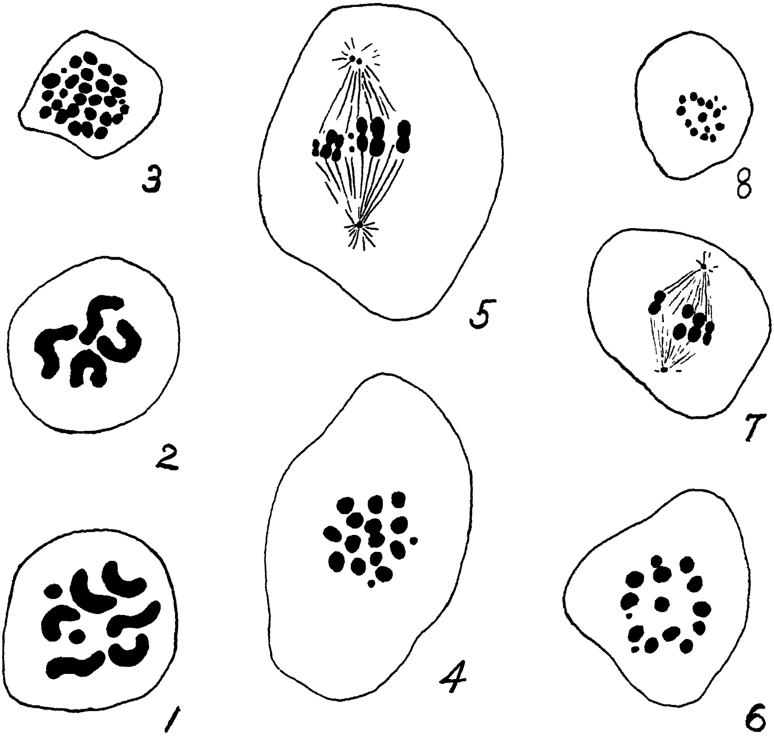
PLATE XXIX



Spermatogonia, spermatocytes and spermatids of Lethocerus

1. Polar view of metaphase of spermatogonium in *L. americanus*
2. Polar view of metaphase of spermatogonium in a Lethocerus with four chromosomes
3. Polar view of metaphase of spermatogonium of a Lethocerus from New Orleans showing 28 chromosomes. It is believed that there really are thirty here (see text)

4–5. Polar and lateral views of metaphase of primary spermatocytes of Lethocerus from New Orleans

6–7. Polar and lateral views of metaphase of secondary spermatocytes of Lethocerus from New Orleans

8. Polar view of spermatid chromosomes from New Orleans

LIMNETIC DISTRIBUTION AND MIGRATION OF CORETHRA LARVAE IN TWO MICHIGAN LAKES *

FRANK E. EGGLETON

INTRODUCTION

DURING the period from February, 1923, to February, 1929, the writer was engaged upon an ecological study of profundal bottom fauna in several Michigan and New York lakes (Eggleton, 1931). One of the typical profundal benthic types usually present in the bottom mud was the larva of *Corethra punctipennis* Say. Because these larvae were known to occur frequently in the plankton and since their presence in that association would thereby reduce the population of the bottom mud, it was thought desirable to determine how numerous they were in the open water at the time bottom samples were taken. This study of the limnetic distribution of Corethra larvae was originally undertaken entirely for the sake of such information as it might yield regarding the major problem dealing with occurrence of these and other benthic animals in the mud and with their general ecological relations. It soon became evident, however, that the limnetic distribution of Corethra larvae in the lakes being studied was a problem in itself, and one requiring more time and effort than could then be spared for it. Accordingly, that phase of the larger investigation was prosecuted less intensively, with only occasional records being taken until the summer of 1929, when it became, itself, the major problem under investigation. During 1929 and 1930 vertical migration and distribution of Corethra larvae in the open lake water has been studied, principally in

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* Contribution from the University of Michigan Biological Station and from the Zoölogical Laboratory of the University of Michigan.

Douglas Lake, Cheboygan County, and Third Sister Lake, Washtenaw County, Michigan. This paper presents results for the whole period, June, 1926, to March, 1931, during which limnetic distribution of these larvae has been under consideration.

Juday (1904, 1908, 1921, 1922) has reported upon diurnal movement of plankton organisms including Corethra larvae and upon abundance, distribution and general biology of this insect in certain Wisconsin lakes. He found a maximum population of 33,800 larvae per square meter of lake bottom in Lake Mendota bottom mud during December, 1917. In the same lake full-grown larvae of *C. punctipennis* were absent from the limnetic habitat during the day, but made a vertical migration from bottom to surface (23.5 meters) and back to the bottom during the night. Partly grown larvae were found to occupy the water below 10 meters during the daytime and to migrate to the surface during the night. In Devils Lake, Wisconsin, the same investigator found full-grown larvae of *C. plumicornis* Fabricius occupying the water during the daytime and thus revealing the same sort of daytime distribution as shown by *C. punctipennis* at night in Lake Mendota. Corethra (sp.?) larvae are frequently mentioned in textbooks as a common constituent of the plankton; presumably day plankton is referred to.

Methods and equipment

Throughout the present investigation samples of bottom mud were obtained by using an Ekman-Birge dredge, which collected a sample of 225 sq. cm. surface area. Mud samples were emptied into a pail, mixed to a uniform consistency with the hand, transferred to a deep-sided pan provided with a brass wire screening with mesh fine enough to retain the young larvae; and the fine mud was separated from the animals and coarser débris by briskly washing the pan up and down in the lake. Since no water was poured into the pan — water used in washing came in through the screen bottom — all possibility of contaminating the samples from this source was avoided. The residue from this washing, containing the coarser débris and the captured animals, was taken to the laboratory in numbered bottles, where the Corethra larvae and pupae were sorted out and counted while still alive.

Practically all collections made in the limnetic habitat were taken with a closing plankton net (Juday, 1916, pp. 573–575; Pl. XXXIV, Figs. 1–3) equipped with No. 6 bolting cloth and having a top opening 10.5 cm. in diameter. The No. 6 bolting cloth increased the calculated efficiency of the net to 92 per cent, and yet this size of mesh (28 per cm.) probably caught even the youngest Corethra larvae present in the water. The collections were emptied into numbered bottles and later, in the laboratory, the larvae were sorted according to size and counted. A plankton trap (Juday, 1916, pp. 578–580; Pl. XXXV, Figs. 1–2) was used on a few occasions during 1930, principally as a means of checking the efficiency of the closing net. Comparison of net and trap collections indicated that the efficiency of the net probably exceeded the calculated value of 92 per cent.

The length of each larva taken in certain collections was measured under a compound microscope by a Leitz "step" ocular micrometer, with the instrument so adjusted that 20 steps on the ocular micrometer scale extended over exactly 1.0 mm. on a stage micrometer. A glass slide was placed on the microscope stage and about ten larvae previously anesthetized by exposure to chloroform vapor were laid along the middle of the slide. Care was taken to prevent stretching the specimens and yet to have them fully extended. All measurements were made to the nearest whole micrometer step (0.05 mm.) and always with the beak and tail-fan extending ventrad. Measurements, therefore, include neither of these structures.

Temperatures were taken with Negretti-Zambra reversing thermometers. Procedures outlined in *Standard Methods of Water Analysis* (1925) were followed in chemical analyses. Hydrogen ion concentration was determined colorimetrically; dissolved oxygen, by the Rideal-Stewart modification of the Winkler method; and free carbon dioxide, bicarbonates and carbonates, by procedures described in the previously mentioned standard methods; N/50 H_2SO_4, N/44 KOH, phenolphthalein and methyl orange were used in the titrations. Water was collected with the modified

Kemmerer water bottle (Birge, 1922, pp. 547–549; Pl. XL, Figs. 6–7) and all chemical analyses, except final titrations, were made in the field at the time of sampling.

LIMNETIC DISTRIBUTION

Douglas Lake

Corethra punctipennis Say[1] is the only representative of this genus which has been reported from either Douglas or Third Sister Lake. In the former, summer populations of Corethra larvae found occupying bottom mud were not large and even by late October (1928 and 1930) the number of these larvae per square meter of lake bottom was less than 4,000. The minimum found in Third Sister Lake within the deepest profundal zone (1,520) occurred late in August and the maximum of more than 71,000 per square meter was found in January (Eggleton, 1931).

Douglas Lake has one minor and six major depressions (Welch, 1927), each behaving in many ways like an isolated lake and showing clearly defined depression individuality in several respects. It is frequently necessary, therefore, in studying limnological phenomena in that lake, to treat each depression as though it were a separate lake. This procedure was adopted for work on limnetic distribution of Corethra larvae and data presented in Table II are arranged according to depressions.

Practically all sampling in the limnetic zone during 1926, 1927 and 1928 was confined to South Fish-Tail depression, and data for representative hauls during those years are given in Table II. None of the 1926 vertical series of samples showed larvae above the 20-meter stratum and in this respect they resemble the data for the summer of 1928. These results are not consistent with those for 1927, when only a few series were taken, nor with those of 1929 and 1930, when many were obtained. The small number of larvae found in 1926 may possibly be explained by the fact that all limnetic samples for that summer were taken during late July and early August, when the population of Corethra larvae is usually at its annual minimum, both in the benthic and in the limnetic habitat. Such an explanation is not applicable, however, to the 1928 data, which were nearly all gathered during late June, before the annual midsummer minimum was reached. This difference between the results for the seasons of 1926 and 1928 and those for other years offers further support for the statement of Welch (1927, p. 443) pointing out "the possible inadequacy of a single season's results as a dependable index of the expected sequence of events in a lake environment."

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[1] The writer is indebted to Professor O. A. Johannsen for identification of both the larvae and adults. Professor Johannsen identified the material as *Chaoborus punctipennis* Say, giving the name *Corethra* as a synonym. The author, however, prefers to use the established and better known name, Corethra.

Corethra larvae were consistently found below depths of 10 meters in the open water of South Fish-Tail depression during the summer months (June, July, August) of 1927, 1929 and 1930. There were but few exceptions to this statement in all records for these three years. The exceptions, e.g. July 1, 1929, usually consisted in a restriction of larvae to depths below 15 meters.

Distribution and depression individuality. — It has been clearly demonstrated (Welch, 1927; Eggleton, 1931; Welch and Eggleton, 1932) that the different depressions of Douglas Lake show marked differences in their physical, chemical and biological behavior. Additional evidence of depression individuality in biological terms is to·be found in Table II. Despite the ever present tendency to vary from day to day, which has been evident in both lakes discussed from the beginning of this investigation, depth distribution of Corethra larvae in the limnetic zone of different Douglas Lake depressions shows certain definite dissimilarities.

Distribution in South Fish-Tail depression during the summer months was generally characterized by an absence of larvae down to a depth of 10 meters; the presence of a few larvae per cubic meter in the 10–15-meter stratum; a sudden increase to populations of 100–300 per cubic meter within the 15–20-meter stratum; and the occurrence below 20 meters of a population intermediate in number between that of the 10–15- and that of the 15–20-meter stratum. Sedge Point and Roberts Point depressions show the same type of distribution. Grapevine Point depression, on the contrary, uniformly exhibited a limnetic distribution below 10 meters, in which the number of larvae per cubic meter increased with increase of depth. In Fairy Island depression the exact opposite of this last type of distribution was found late in the season each year, i.e. there was an inverse ratio between depth below 10 meters and number of larvae per cubic meter. However, in the same region earlier in the season the distribution of larvae agreed with that in South Fish-Tail, Roberts Point and Sedge Point depressions. Stony Point depression was at times erratic, but usually showed a limnetic distribution of larvae like that found in Grapevine Point depression. All data available on distribution in Maple Point depression are presented in Table II. Despite the fact that only four series of samples have been taken in that region of the lake the entire agreement of these four series, representing as they do four different years, argues for their reliability. On no occasion were Corethra larvae found at any depth in that depression.

It might be possible to postulate causes of these differences found in limnetic distribution of Corethra larvae in different depressions. It could, for instance, be pointed out that there are several apparent correlations between physico-chemical conditions in each area of deeper water and distribution of larvae. However, the writer cannot avoid the conviction, especially in the light of frequent inconsistencies, apparent in Douglas Lake but even more evident in Third Sister Lake, as Table III shows, that data for at least several more years must be accumulated and studied before many generalizations can be stated. Perhaps the most probable of these possible correlations occurs between the type of distribution found in Grapevine Point and Stony Point depressions and the general lack of thermal stratification and chemical stagnation which characterizes these regions of the lake.

Another instance in which data from the several depressions differed was in length of the larvae taken from similar strata and on the same or comparable dates, but from different depressions. Thus, between July 25 and August 1, 1930, larvae taken from each of the major depressions were measured and found to show a considerable variation in size within the same stratum (Table I).

TABLE I

BODY LENGTH OF LARVAE IN MILLIMETERS

Strata	Depressions					
	South Fish-Tail	Roberts Point	Fairy Island	Stony Point	Sedge Point	Grapevine Point
10–15 m.	r = 5.95–6.50 a = 6.20	r = 3.70–5.05 a = 4.50	....	r = 2.95–3.45 a = 3.15	r = 2.45–3.35 a = 2 95	r = 3.85–4.25 a = 4.05
15–20 m.	r = 4.45–5.05 a = 4.65	r = 4.80–6.20 a = 5.25	r = 3.75–5.65 a = 4.55	r = 2.90–4.05 a = 3.60	r = 3.00–4.30 a = 3.70	r = 3.00–4.30 a = 3.70
20–bottom	r = 6.55–7.25 a = 6.90	r = 5.40–6.35 a = 5.95	r = 4.50–7.65 a = 5.40	....	r = 5.40–6.00 a = 5.70	r = 3.00–4.15 a = 3.45

Abbreviations: r, range of size in millimeters; a, average size in millimeters

Seasonal variation in distribution. — During the summer some tendency to show seasonal variations in size and abundance of larvae in the limnetic zone was noticed. Such variations were usually masked, however, unless samples were taken within the same area, on very frequent occasions, from strata of not more than two or three meters in extent, and during approximately the same period of the day. This was not usually feasible. Even so, the data in Table II do show some evidence of quantitative seasonal variations during the summer months.

The writer visited Douglas Lake on two occasions during the period of the autumnal turnover (Oct. 20, 1928; Oct. 18, 1930). On both dates the lake was found to be thoroughly mixed from top to bottom, with the water practically homothermous and nearly chemically uniform throughout. No larvae were found in the limnetic zone above the 15–20-meter stratum at the time of the first visit; in October, 1930, none were collected above the 20-meter level during the daytime. These records were in sharp contrast to results for the summers of 1927, 1929 and 1930, but resembled some of the summer records for 1926 and 1928. These fall records could not be regarded as significant if it were not for the fact that they agree with records obtained late each autumn in Third Sister Lake (Table III).

Third Sister Lake

The physiography and morphometry of Third Sister Lake has been described in detail by the author in an earlier paper (Eggleton, 1931) and need not be dealt with here. It is morphometrically greatly different from Douglas Lake, and this is reflected in the different limnetic distribution of Corethra larvae in the two lakes.

One feature of the distribution in Third Sister Lake (Table III) which was apparent was the occurrence of larvae at noticeably higher levels than in Douglas Lake. In the former, larvae were usually present up to depths of 5 meters, were frequently found 2 or 3 meters below the surface, and at times were taken even within the 0–1-meter stratum during the day.

Seasonal variation in distribution. — Sampling operations have been conducted in Third Sister Lake at all seasons of the year except midsummer. There are several records from this lake for June and September, one for August, but none for July. For the remainder of the year, however, a considerable number of data are available. The records presented in Table III have been selected from a larger series to show the principal features observed.

Beginning with late summer or early fall the annual ecological cycle of events included a seasonal variation in limnetic distribution of Corethra larvae. Throughout early and middle autumn larvae occurred in considerable abundance at all depths below 5 meters (Nov. 2, 1926; Sept. 27–Nov. 15, 1927; Oct. 10, 1928; Table III). Late in the fall, after the autumnal overturn had been in progress for some time, the population in the open water decreased greatly until no larvae occurred above the 15-meter level, and even below that depth the population was much less dense than it had been earlier in the season (Nov. 21–29, 1927; Nov. 10–Dec. 15, 1928; Nov. 29, 1929; Nov. 12, 1930; Table III.) From about the time the first permanent ice coat formed until midwinter, there appeared a slow but quite steady trend back toward a large limnetic population. This tendency culminated in February, when the annual maximum was attained. It is important to note that this annual maximum for the limnetic zone coincided with the annual midwinter maximum for the benthic habitat and thus represents a period of the year when the whole lake was heavily populated with these larvae. Very shortly after the ice disappeared, usually by the first week of April, the fully grown larvae began to pupate and emerge. The decline thus initiated continued throughout spring and summer until the annual minimum was reached, probably in late August.

Ice usually prevented work on the lake during most of March, but the few records available for early spring (e.g. March 11, 1931; April 7, 1928; May 8, 1929; Table III) seem to indicate a decline in limnetic Corethra population during the vernal overturn comparable to that which occurred late in the autumnal circulation period.

VERTICAL MIGRATION

The first net hauls taken to determine vertical distribution of Corethra larvae in Douglas Lake were made during the summer of 1926. It has been pointed out that none of the day samples collected above 20 meters in that year contained larvae and on certain occasions no larvae were found in the water at any depth. It seemed evident, however, that the larvae were making nocturnal migrations into the upper water, since on mornings after heavy on-shore winds had blown all night the beach was often strewn with larvae both partly and fully grown.

On August 13–14, 1926, a series of both day and night samples was taken in South Fish-Tail depression to determine whether such vertical migration could be demonstrated (Table IV). The first set of samples was taken at 9:00 A.M., August 13, and the results were entirely negative; no Corethra larvae were found in the water at any depth. At noon another set of hauls was made and 50 larvae per cubic meter were found in the 20–23-meter stratum, but none above that level. At 4:00 P.M. the number of larvae in the same stratum was 125 per cubic meter and again none occurred higher up in the lake. The next set of samples, taken at 8:00 P.M., showed that the larvae were beginning to leave the mud, since 125 per cubic meter were found in the water between 20 and 23 meters and there were also 20 per cubic meter in the 15–20-meter stratum. The migration upward progressed so that by 10:00 P.M., when the fifth set of hauls was made, there were larvae as far up as the 5-meter level. When the final set of hauls in the series was made at 2:00 A.M., August 14, the larvae were taken only in the 20–23-meter stratum. It is unfortunate that neither the samples taken at 10:00 P.M. nor those taken at 2:00 A.M. were examined until next day, since otherwise additional hauls could have been made before and after 2:00 A.M. It was evident, however, that the larvae made vertical migrations at least into the epilimnion and perhaps to the surface.

Another series of day-night samples consisting of seven sets of hauls was taken in South Fish-Tail depression between 9:00 A.M. and 9:00 P.M., July 16, 1930 (Table IV).

It should be remembered that larvae were found occupying the water in this depression up to depths of about 10 meters during the day throughout the summer of 1930. As was typical of the whole season in that part of the lake, the maximum population per cubic meter occurred between the depths of 15 and 20 meters from 9:00 A.M. to 5:00 P.M. The smallest total limnetic population was found at 1:00 P.M., although the distribution of larvae was perhaps not significantly different from that at 9:00 A.M. or 3:00 P.M.

The first significant increase within the limnetic zone was noted in the 5:00 P.M. set of samples and this was still more pronounced by 7:00 P.M., but even at the later hour the larvae had not progressed above the 10-meter level. At 8:00 P.M., however, they had invaded the 5–10-meter stratum and a slightly increased population was found in all the lower strata. The final set of samples (9:00 P.M.) showed a considerable augmentation of the number of larvae at all levels in the lake which they had previously occupied and in addition there were 88 larvae per cubic meter in the 3–5-meter stratum, thus conclusively demonstrating a nocturnal migration of these larvae during the summer in Douglas Lake.

In view of the divided opinion among biologists concerning the primary function of the two pairs of air sacs in the body of Corethra larvae (Krogh, 1911; Frankenberg, 1915; Ege and Bardenfleth, 1916; Akehurst, 1922; Damant, 1924; Pearse, 1926, pp. 223, 226; Carpenter, 1928, p. 189), determination of the behavior of these animals during the circulation period seemed to offer the possibility of interesting and perhaps significant data. If the function of the air sacs is entirely respiratory and diurnal migration of the larvae is for the purpose of filling these sacs with a reserve supply of oxygen to last them through the period spent in the oxygenless hypolimnion or profundal benthic mud, then at least the *need* for such migrations would not exist during the overturns. Further, several workers have observed the light reactions of Corethra larvae and Juday (1921, p. 278) states: "While the larvae of *Corethra punctipennis* give a prompt negative reaction to light, yet it hardly seems probable that their extensive depth migration in Lake Mendota, even including a descent into the mud, is a simple light phenomenon." It appeared possible, therefore, to secure another bit of useful evidence by determining whether these larvae migrated toward the surface at night and down again during the day when ice on the lake was covered with a thick, light-reducing layer of snow.

Accordingly, on two occasions in 1927, January 5–6 and November 21–22 (Table V), a series of day-night catches were made in Third Sister Lake to determine whether these larvae migrated into the upper waters (1) during the winter when the lake was covered with ice and snow, and (2) during the autumnal overturn when the lake was completely aërated from surface to bottom. On both dates there was a very evident nocturnal migration into the upper waters. During the night of January 5–6 the larvae were not taken above the 5-meter level, although the first larvae had reached that stratum by 7:00 P.M. and the number increased at that depth up to midnight. By 2:00 A.M., however, there were none above 7 meters; at 4:00 A.M. they had all returned to depths below 10 meters, and by 6:00 A.M. there were none above the 15-meter level. The set of samples taken at 7:00 A.M. showed larvae distributed essentially as they were on the preceding afternoon at 2:00 P.M.

On the afternoon of November 21 at 4:00 P.M. there were larvae in the water up to the 5-meter stratum. At 6:00 P.M., they had reached the 3-meter depth; at 9:00 P.M. there were 50 per cubic meter in the 2–3-meter stratum; by 11:00 P.M. there were 25 per cubic meter between 1 and 2 meters; and at 3:00 A.M. the larvae had reached the surface. A series begun at 8:00 A.M. showed that there were no larvae above the 10-meter level.

The series of hauls made on October 18, 1930, in South Fish-Tail depression of Douglas Lake (Table IV) began at 10:00 A.M. and ended with the set of samples taken at 6:00 P.M.; nevertheless it shows what appears to be the beginning of a migration into the upper water. Another feature which was manifested by this series was absence of larvae from all but the lowest levels during the day. This coincides with the usual distribution found in Third Sister Lake after the autumnal overturn had been in progress for some time.

Four sets of vertical hauls were made between 11:00 A.M. and 3:00 P.M. on January 28, 1931, in Third Sister Lake. The results agree closely with those for January 23, 1928, but do not agree with the data for January 5, 1927. This is perhaps due to the fact that on the date last mentioned the lake had been covered with ice less than half as long as it had been on the occasions of the series of January, 1928, and January, 1931.

It may be pointed out that demonstration of nocturnal migration into the upper water on January 5–6, 1927 (Table V) within three weeks after the lake had frozen over — the series had been taken as soon as safe ice covered with several inches of snow was available — was much more significant than it would have been weeks later after the establishment of typical midwinter conditions. Thermo-chemical conditions were not greatly different on January 5–6 from those just previous to formation of the ice cover and thus the only factor materially varied was light, a considerable portion of which must have been excluded from the water throughout the whole twenty-four hours of the day by the thick cover of ice and snow.

LARVAL SIZE GROUPS

Juday (1921, p. 277) states that "only rarely was an individual found in the mud which was estimated to be only one-third as large as a full-grown larva and frequently individuals were obtained from the water which were recorded as half grown. Thus, it appears that the young larvae inhabit the lower water in the daytime instead of the mud until they are approximately one-third grown, or perhaps a little larger."

In Third Sister Lake Corethra larvae from bottom samples always showed three different sizes during late autumn, winter and early spring. In summer there were different sizes present, but the division into three distinct groups did not seem evident. On November 10, 1926, bottom mud was collected from the 18-meter depth, the Corethra larvae were removed, and their lengths were measured. Similar samples were collected on November 17, 1926, April 16, 1927, and January 23, 1928, and the Corethra larvae were kept for measurement.

Figures 13–16 present the data in the form of size-frequency graphs. Several facts common to each figure will be easily seen. The trimodal curve of each graph proves conclusively the existence of three distinct size groups. These different sizes represent different broods; hence, they are also age groups. The largest larvae are, in all figures, practically fully grown; the medium-sized larvae about three fourths grown; and the smallest approximately half grown. On each date the most numerous group was composed of half-grown larvae; the fully grown individuals were next in point of abundance; and those three fourths grown were least numerous.

When data for November 10, November 17, January 23 and April 16 are compared in this order, it is evident that these larvae continue to grow slowly throughout the winter, As would be expected, the so-called full-grown larvae made the least growth. It may even be possible that the increase in length from 10.5 mm. on November 10, 1926, to 10.75 mm. on April 16, 1927, is not significant. Both the other groups, however, made an evident growth, as the curves show, of about 1 mm. between November 10 and April 16. It is true that the curve for January 23 is based on data for another year and it might be urged that the interpolation is not justified. The very fact, however, that these data fit in so well is strong supporting evidence for the actuality of larval growth shown by the other curves. It is obvious, also, that, even if the January data had been obtained in 1927 instead of 1928, the larvae measured would not have been the same individuals as those measured in November and in April.

The full-grown larvae appear, even in late autumn, to be in the last larval instar, but are prevented from pupating by some factor or factors — perhaps the *falling* temperature of the water — present until spring when, perhaps owing to the *rising* temperature, they pupate and emerge in the first spring swarms. Indirect evidence which seems to point toward temperature change as an important factor is afforded by observations on larvae brought into the laboratory during the winter. Such larvae did not pupate while kept in a temperature at or below that of the lake at the time they were collected. If, however, the tempera-

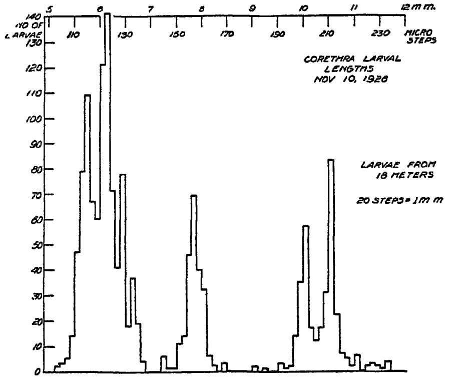

FIG. 13

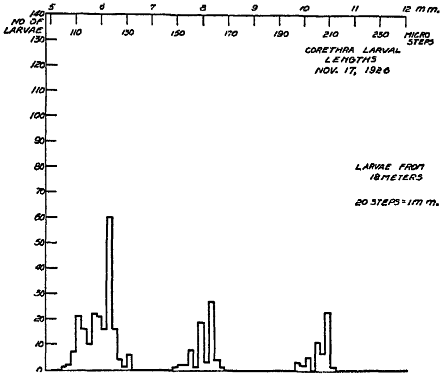

FIG. 14

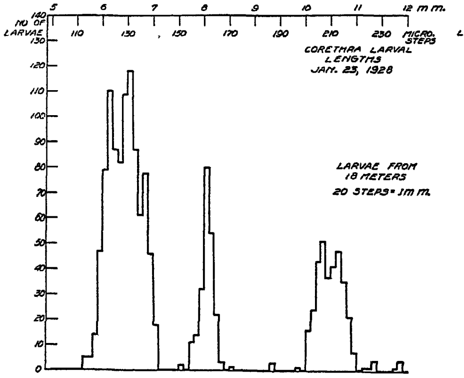

FIG. 15

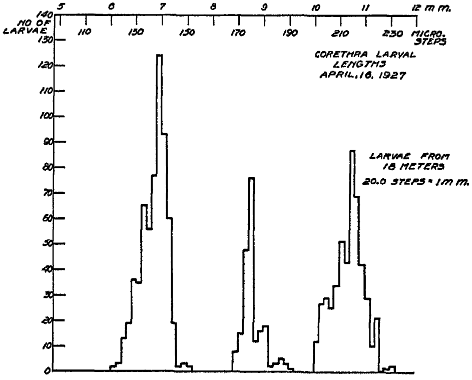

FIG. 16

FIGS. 13–16. Size-frequency curves of body length of Corethra larvae from Third Sister Lake profundal benthic zone ture was allowed to rise even a few degrees, they soon pupated. And if the temperature was gradually raised to 15–20° C. over a period of 24–48 hours and at the same time the water was kept well aërated, the larvae began at once to pupate and the duration of the pupal stage was noticeably shortened.

During the period July 27–August 4, 1930, a total of 926 larvae, collected in bottom samples from each major depression

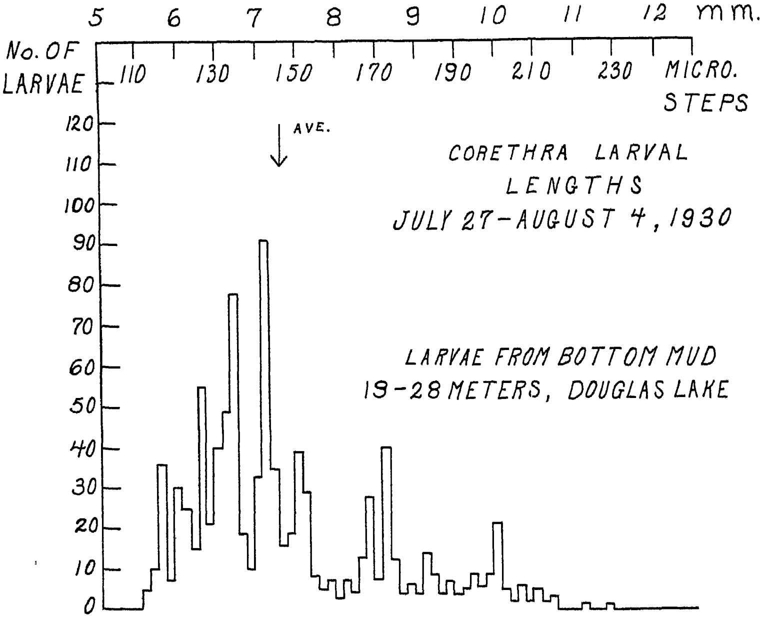

FIG. 17. Size-frequency curve of body length of Corethra larvae from profundal benthic zone within the six major depressions, Douglas Lake

of Douglas Lake, were measured. Figure 17 is a size-frequency curve drawn from the data. The range, 5.5–11.5 mm., indicates that approximately the same size-age groups were present as in the winter population in Third Sister Lake. The average size of 7.25 mm. shows clearly, however, that the majority of the population was composed of partly grown larvae. There is perhaps some hint of three modes of 7.0, 8.5 and 10.0 mm., but the numerical reduction of larger larvae practically obscures this feature of the graph. The fact that the curve does not end abruptly at about 8 mm., but instead slowly declines with two faintly developed modes beyond and with some scattered individuals in the population having a body length greater than 10.5 mm., shows a correlation with the writer's observations on character, size, periodicity and time of the emergences of these insects during the summer at Douglas Lake. Figures 13–17 indicate that larvae occupying the bottom mud in these two lakes, both summer and winter, range in size from about one half to fully grown larvae.

Larvae from three strata (10–15, 15–20, 20–28 meters) within the limnetic zone in the six major depressions of Douglas Lake were collected between July 25 and August 1, 1930, and measured. Data comprising body lengths of 533 larvae are presented in the three size-frequency curves of Figure 18. Larvae varied in both size and abundance in the three different strata. The smallest population occurred in the 10–15-meter stratum and the largest between 15 and 20 meters; larvae from the 20–28-meter level occupied a numerically intermediate position. It should be mentioned in passing that records for the latter stratum were a composite of data from all depths below 20 meters in each depression. This stratum was not, then, always 8 meters thick, but varied from 2 to 8 meters in depth according to the depression.

The increase in size of larvae corresponds with increase of depth, the average length in the 10–15-meter stratum being 3.8 mm.; for the 15–20-meter level, 4.3 mm.; and for the 20–28-meter depth, 5.2 mm. The extreme range of the limnetic larvae was 2.45–7.65 mm., which in terms of size-age groups showed them to be ranging from very young larvae to those nearly three fourths grown. Individuals which in size approached the length of larvae three fourths grown were very few, however, and the majority of the limnetic population should be said to range up to about the half-grown size. As would be expected, there was some overlapping in size of the largest larvae from the water and the smallest from the mud.

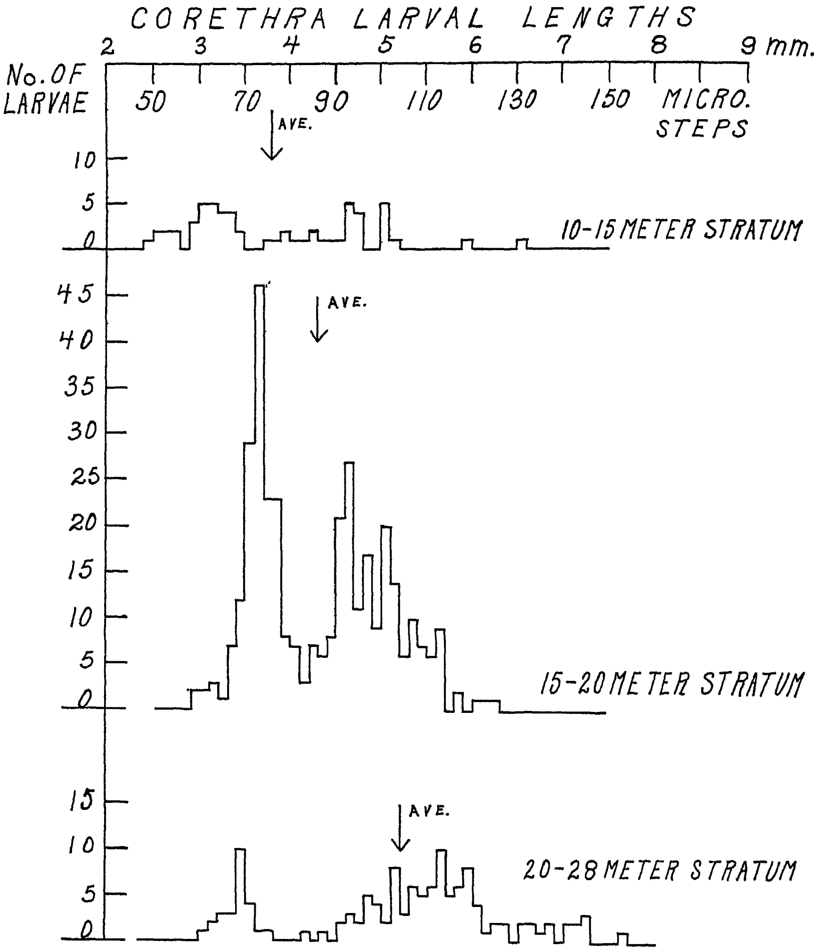

FIG. 18. Size-frequency curves of body length of Corethra larvae from the limnetic zone within the six major depressions, Douglas Lake. Larvae collected between July 25 and August 1, 1930

SUMMARY

1. Data concerning limnetic distribution and vertical migration of the larvae of *Corethra punctipennis* Say in Douglas Lake, Cheboygan County, and Third Sister Lake, Washtenaw County, Michigan, gathered during the period from June, 1926, to March, 1931, are presented.

2. Throughout the investigation bottom samples were collected with a small Ekman-Birge dredge; limnetic collections made with a closing plankton net; temperatures taken with Negretti-Zambra thermometers; and procedures outlined in *Standard Methods of Water Analysis* followed in chemical determinations.

3. Records for Third Sister Lake cover all seasons of the year except midsummer, but work on Douglas Lake was largely confined to June, July and August, with the addition of two visits during the fall overturns (October, 1928 and 1930).

4. Data for the summers of 1926 and 1928, largely derived from work on one of six major depressions in Douglas Lake, differ in certain respects from the records of 1927, 1929 and 1930 and thus emphasize "the possible inadequacy of a single season's results as a dependable index of the expected sequence of events in a lake environment."

5. Limnetic distribution of Corethra larvae differed in the several depressions of Douglas Lake in these respects: (1) the size of larvae occupying the same strata in different depressions; (2) the number of larvae per cubic meter; and (3) the thickness of the upper stratum, from which larvae were uniformly absent.

6. Seasonal variation in size, abundance and distribution of limnetic larvae, usually masked during midsummer in Douglas Lake, was clearly evident in Third Sister Lake during the remainder of the year.

7. Nocturnal migration into the upper water of Douglas Lake occurred in summer, and the same larval behavior was observed in Third Sister Lake (1) late in the autumnal circulation period and (2) in winter, when ice on the lake was covered with a thick layer of snow.

8. Larvae from the limnetic zone in Douglas Lake and from bottom mud in Douglas and Third Sister lakes were measured and found to show the following distribution and variations in size:

(*a*) In Douglas Lake, limnetic larvae increased in size (2.45–7.65 mm.) with increase in depth.

(*b*) Midsummer larvae from bottom mud in Douglas Lake ranged in length from approximately 5.5 mm. to 11.5 mm.

(*c*) Larvae from the profundal benthic zone in Third Sister Lake varied in body length from 5.10 mm. to 11.65 mm. in November and from 6.0 mm. to 11.75 mm. in April, the smallest larvae thus showing a winter growth of about 1 mm.

(*d*) Three size-age groups were evident in the winter larvae from Third Sister Lake.

(*e*) Larvae occupying the limnetic habitat were thus found to be half grown or smaller, while those from bottom mud comprised three groups — half grown, three fourths grown, and fully grown.

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TABLE II

Limnetic Distribution of Corethra Larvae in Douglas Lake

South Fish-Tail Depression

Station 1

Date and time	Strata meters	No. larvae per cu. m.	Date and time	Strata meters	No. larvae per cu. m.	Date and time	Strata meters	No. larvae per cu. m.
1926	0–5	0	July 1	0–5	0	July 16	0–5	0
Aug. 13	5–10	0	1 P.M.	5–10	0	3 P.M.	5–10	0
12 M.	10–15	0		10–15	0		10–15	15
	15–20	0		15–20	230		15–20	135
	20–23	50		20–23	92		20–22	62
1927	0–5	0	July 9	0–5	0	July 19	0–5	0
July 2	5–10	0	9 A.M.	5–10	0	9 A.M.	5–10	0
9 A.M.	10–15	19		10–15	5		10–15	20
	15–20	220		15–20	175		15–20	268
	20–23	92		20–23	44		20–22	25
1928	0–10	0	July 17	0–5	0	July 31	0–10	0
June 27	10–15	0	5 P.M.	5–10	0	10 A.M.	10–15	10
2 P.M.	15–20	0		10–15	42		15–20	170
	20–23	16		15–20	308		20–22	50
				20–23	28			
Oct. 20	0–3	0				Aug. 14	0–5	0
11 A.M.	3–9	0	Aug. 13	0–5	0	11 A.M.	5–10	0
	9–12	0	3 P.M.	5–10	0		10–15	20
	12–15	0		10–15	0		15–20	185
	15–18	40		15–20	75		20–22	63
	18–21	40		20–23	42			
	21–23	38				Oct. 18	0–5	0
			1930	0–5	0	10 A.M.	5–10	0
1929	0–5	0	July 7	5–10	0		10–12	0
June 20	5–10	0	3 P.M.	10–12	21		12–15	0
5 P.M.	10–15	92		12–14	42		15–18	0
	15–20	225		14–16	126		18–20	0
	20–23	56		16–18	271		20–23	117
				18–20	146			
				20–22	42			

TABLE II (*continued*)

Station 10 Grapevine Point Depression

Date and time	Strata meters	No. larvae per cu. m	Date and time	Strata meters	No. larvae per cu. m.	Date and time	Strata meters	No. larvae per cu. m.
1929	0–5	0	Aug. 12	0–5	0	July 28	0–5	0
June 20	5–10	0	8 A.M.	5–10	0	9 A.M.	5–10	0
3 P.M.	10–15	25		10–15	0		10–15	15
	15–20	125		15–20	183		15–20	90
	20–23	175		20–23	205		20–23	116
July 15	0–5	0	1930	0–5	0	Aug. 1	0–5	0
1 P.M.	5–10	0	July 8	5–10	0	2 P.M.	5–10	0
	10–15	10	1 P.M.	10–15	17		10–15	5
	15–20	70		15–20	116		15–20	155
	20–23	100		20–23	150		20–23	188

Station 20 Sedge Point Depression

Date and time	Strata meters	No. larvae per cu. m	Date and time	Strata meters	No. larvae per cu. m.	Date and time	Strata meters	No. larvae per cu. m.
1929	0–5	0	1930	0–5	0	Aug. 16	0–5	0
June 27	5–10	0	July 29	5–10	0	10 A.M.	5–8	0
8 A.M.	10–15	0	11 A.M.	10–15	25		8–10	0
	15–20	240		15–20	125		10–12	0
	20–24	181		20–24	63		12–14	0
July 17	0–10	0	Aug. 1	0–10	0		14–15	0
9 A.M.	10–15	50	4 P.M.	10–15	30		15–20	185
	15–20	263		15–20	110		20–23	50
	20–24	125		20–24	69			

Station 30 Fairy Island Depression

Date and time	Strata meters	No. larvae per cu. m	Date and time	Strata meters	No. larvae per cu. m.	Date and time	Strata meters	No. larvae per cu. m.
1929	0–5	0	July 15	0–10	0	July 25	0–5	0
June 20	5–10	0	9 A.M.	10–15	0	9 A.M.	5–10	0
9 A.M.	10–15	0		15–20	80		10–15	0
	15–20	95		20–25	65		15–20	135
	20–25	105		25–28	33		20–25	120
	25–28	58	Aug. 10	0–10	0		25–28	100
July 6	0–5	0	9 A.M.	10–15	0	Aug. 1	0–5	0
9 A.M.	5–10	0		15–20	34	9 A.M.	5–10	0
	10–15	0		20–25	58		10–15	0
	15–20	105		25–28	42		15–20	245
	20–25	111	1930	0–15	0		20–25	146
	25–28	75	July 8	15–20	195		25–28	83
			8 A.M.	20–25	155			
				25–28	75			

TABLE II (*concluded*)

Date and time	Strata meters	No. larvae per cu. m.	Date and time	Strata meters	No. larvae per cu. m.	Date and time	Strata meters	No. larvae per. cu. m.
Station 40			Stony Point Depression					
1929	0–5	0	Aug. 12	0–5	0	July 29	0–5	0
June 29	5–10	0	4 P.M.	5–10	10	9 A.M.	5–10	0
3 P.M.	10–15	30		10–15	25		10–15	45
	15–19	43		15–19	206		15–19	250
July 16	0–5	0	1930	0–5	0	Aug. 1	0–5	0
1 P.M.	5–10	0	July 15	5–10	0	3 P.M.	5–10	5
	10–15	40	8 A.M.	10–15	55		10–15	15
	15–19	43		15–19	19		15–19	218
Station 50			Roberts Point Depression					
1929	0–5	0	July 16	0–10	0	Aug. 1	0–5	0
June 21	5–10	0	8 A.M.	10–15	20	11 A.M.	5–10	0
2 P.M.	10–15	45		15–20	155		10–15	15
	15–20	285		20–22	75		15–20	145
	20–22	138					20–22	50
			Aug. 10	0–10	0			
June 29	0–5	0	1 P.M.	10–15	5	Aug. 15	0–5	0
11 A.M.	5–10	0		15–20	55	11 A.M.	5–10	0
	10–15	15		20–22	12		10–15	40
	15–20	155					15–21	150
	20–22	75	1930	0–10	0			
			July 25	10–15	56			
			3 P.M.	15–20	170			
				20–22	40			
Station 80			Maple Point Depression					
1923	0–5	0	1926	0–5	0	1930	0–5	0
Aug. 18	5–10	0	Aug. 6	5–10	0	Aug. 1	5–10	0
9 A.M.	10–15	0	12 M.	10–15	0	10 A.M.	10–15	0
			1929	0–5	0			
			Aug. 10	5–10	0			
			9 A.M.	10–15	0			

TABLE III

Limnetic Distribution of Corethra Larvae in Third Sister Lake

Station 1 18 meters

Date and time	Strata meters	No. larvae per cu. m.	Date and time	Strata meters	No. larvae per cu. m.	Date and time	Strata meters	No. larvae per cu. m.
1926	0–5	0	Oct. 18	0–2	0	Nov. 26	0–3	0
Nov. 2	5–10	105	12 M.	2–3	25	2 P.M.	3–5	0
11 A.M.	10–15	345		3–5	38		5–10	0
	15–18	115		5–10	160		10–15	5
				10–15	325		15–18	50
1927	0–5	0		15–18	58			
Jan. 5	5–10	0				Nov. 29	0–3	0
2 P.M.	10–15	20	Oct. 25	0–2	0	11 A.M.	3–5	0
	15–18	207	1 P.M.	2–3	0		5–10	0
				3–5	25		10–15	0
June 9	0–6	0		5–10	125		15–18	25
10 A.M.	6–8	135		10–15	180			
	8–10	90		15–18	116	Dec. 6	0–3	0
	10–12	90				10 A.M.	3–5	0
	12–14	225	Nov. 1	0–3	0		5–10	40
	14–16	315	10 A.M.	3–5	50		10–15	10
	16–18	135		5–10	175		15–18	16
				10–15	425			
Sept. 27	0–2	0		15–18	175	1928	0–3	0
10 A.M.	2–3	175				Jan. 23	3–5	25
	3–5	212	Nov. 8	0–3	0	2 P.M.	5–10	110
	5–10	140	11 A.M.	3–5	25		10–15	20
	10–15	42		5–10	5		15–18	41
	15–18	80		10–15	75			
				15–18	125	Feb. 22	0–1	175
Oct. 4	0–2	0				11 A.M.	1–3	175
2 P.M.	2–3	50	Nov. 15	0–3	0		3–5	538
	3–5	138	1 P.M.	3–5	12		5–10	335
	5–10	20		5–10	100		10–15	100
	10–15	20		10–15	205		15–18	642
	15–18	34		15–18	400			
						April 7	0–5	0
Oct. 11	0–2	0	Nov. 21	0–3	0	4 P.M.	5–10	84
10 A.M.	2–3	0	4 P.M.	3–5	0		10–15	142
	3–5	112		5–10	15		15–18	278
	5–10	150		10–15	20			
	10–15	170		15–18	25			
	15–18	41						

TABLE III (*continued*)

Station 1 18 meters

Date and time	Strata meters	No. larvae per cu. m.	Date and time	Strata meters	No. larvae per cu. m.	Date and time	Strata meters	No. larvae per cu. m.
June 6	0–5	0	1929	0–1	100	May 20	0–3	0
10 A.M.	5–10	135	Feb. 9	1–3	88	12 M.	3–5	0
	10–15	345	1 P.M.	3–5	238		5–10	10
	15–18	92		5–10	410		10–15	105
				10–15	120		15–18	142
Oct. 10	0–1	0		15–18	450			
10 A.M.	1–3	0				Nov. 12	0–3	0
	3–5	0	May 8	0–3	0	3 P.M.	3–5	0
	5–10	60	10 A.M.	3–5	0		5–10	0
	10–15	330		5–10	20		10–15	0
	15–18	84		10–15	105		15–18	158
				15–18	125			
Nov. 10	0–3	0				1931	0–3	0
12 M.	3–5	0	Nov. 29	0–5	0	Jan. 28	3–5	37
	5–10	5	11 A.M.	5–10	0	1 P.M.	5–10	40
	10–15	80		10–15	0		10–15	105
	15–18	275		15–18	183		15–18	116
Dec. 15	0–3	0	1930	0–3	0	March 11	0–5	0
3 P.M.	3–5	0	Feb. 12	3–6	41	10 A.M.	5–10	0
	5–10	0	10 A.M.	6–9	396		10–15	30
	10–15	75		9–12	208		15–18	375
	15–18	208		12–15	209			
				15–18	417			

TABLE IV

VERTICAL MIGRATION OF CORETHRA LARVAE IN DOUGLAS LAKE

Station 1

South Fish-Tail Depression

Date and Time	Strata meters	No. larvae per cu. m.	Date and time	Strata meters	No. larvae per cu. m.	Date and time	Strata meters	No. larvae per cu. m.
1926 Aug. 13 9 A.M.	0–5	0	1930 July 16 9 A.M.	0–5	0	July 16 9 P.M.	0–3	0
	5–10	0		5–10	0		3–5	88
	10–15	0		10–15	15		5–10	90
	15–20	0		15–20	110		10–15	130
	20–23	0		20–22	100		15–20	195
							20–22	537
12 M.	0–5	0	1 P.M.	0–5	0	Oct. 18 10 A.M.	0–5	0
	5–10	0		5–10	0		5–10	0
	10–15	0		10–15	10		10–15	0
	15–20	0		15–20	105		15–20	0
	20–23	50		20–22	38		20–23	117
4 P.M.	0–5	0	3 P.M.	0–5	0	11 A.M.	0–5	0
	5–10	0		5–10	0		5–10	0
	10–15	0		10–15	15		10–15	0
	15–20	0		15–20	135		15–20	0
	20–23	125		20–22	62		20–23	92
8 P.M.	0–5	0	5 P.M.	0–5	0	12 M.	0–5	0
	5–10	0		5–10	0		5–10	0
	10–15	0		10–15	8		10–15	0
	15–20	20		15–20	242		15–20	0
	20–23	125		20–22	83		20–23	100
10 P.M.	0–5	0	7 P.M.	0–5	0	3 P.M.	0–5	0
	5–10	8		5–10	0		5–10	0
	10–15	10		10–15	45		10–15	0
	15–20	40		15–20	195		15–20	0
	20–23	21		20–22	262		20–23	108
Aug. 14 2 A.M.	0–5	0	8 P.M.	0–5	0	6 P.M.	0–5	0
	5–10	0		5–10	10		5–10	0
	10–15	0		10–15	60		10–15	0
	15–20	0		15–20	190		15–20	35
	20–23	166		20–22	325		20–23	150

TABLE V

VERTICAL MIGRATION OF CORETHRA LARVAE IN THIRD SISTER LAKE

Station 1 18 meters

Date and time	Strata meters	No. larvae per cu. m.	Date and time	Strata meters	No. larvae per cu. m.	Date and time	Strata meters	No. larvae per cu. m.
1927	0–5	0	6 A.M.	0–5	0	Nov. 22	0–1	25
Jan. 5	5–10	0		5–10	0	3 A.M.	1–2	100
2 P.M.	10–15	20		10–15	0		2–3	50
	15–18	207		15–18	125		3–5	138
							5–10	75
7 P.M.	0–5	0	7 A.M.	0–5	0		10–15	45
	5–10	40		5–10	0		15–18	166
	10–15	84		10–15	20			
	15–18	120		15–18	103	8 A.M.	0–3	0
							3–5	0
9 P.M.	0–5	0	Nov. 21	0–5	0		5–8	0
	5–10	100	4 P.M.	5–10	15		8–10	0
	10–15	140		10–15	20		10–15	75
	15–18	184		15–18	25		15–18	25
12 P.M.	0–5	0	6 P.M.	0–3	0	1931	0–5	0
	5–10	280		3–5	12	Jan. 28	5–10	50
	10–15	160		5–10	10	11 A.M.	10–15	100
	15–18	440		10–15	35		15–18	91
				15–18	92			
Jan. 6	0–5	0				1 P.M.	0–3	0
2 A.M.	5–7	0	9 P.M.	0–2	0		3–5	37
	7–8	205		2–3	50		5–10	40
	8–9	125		3–5	38		10–15	105
	9–10	125		5–10	35		15–18	116
	10–12	40		10–15	80			
	12–16	40		15–18	67	2 P.M.	0–5	0
	16–17	82					5–10	40
	17–18	205	11 P.M.	0–1	0		10–15	115
				1–2	25		15–18	66
4 A.M.	0–1	0		2–3	100			
	1–2	0		3–5	75	3 P.M.	0–3	0
	2–5	0		5–10	75		3–5	28
	5–10	0		10–15	30		5–10	50
	10–15	80		15–18	84		10–15	110
	15–18	80					15–18	92

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THE HERPETOLOGICAL FAUNA OF THE PIGEON LAKE REGION, MIAMI COUNTY, KANSAS *

HOWARD K. GLOYD

SINCE so much of the formerly heavily wooded areas of eastern Kansas has been cleared for crop raising during the last fifty or sixty years, any section of this territory, even though small, in which primitive conditions have been disturbed relatively little, has many points of interest for a student of the natural history and distribution of animals. Such a region is found in southern Miami County, approximately ten miles west of the Kansas-Missouri state line, and the amphibian and reptilian fauna of that region forms the subject of this report.

The area under consideration is characteristically river-bottom swamp land, with occasional rocky bluffs and prairie of an elevation of somewhat more than one thousand feet. The average annual rainfall is between thirty-five and forty-five inches and the principal surface rocks consist of a "variety of shales and intercalated sandstones, with some thin, discontinuous beds of limestone," the La Cygne shale of the Pennsylvanian system (Moore, 1920, p. 28). The forests bordering the streams are dominantly oak, hickory and walnut.

The central point from which collecting activities were carried on is a small, shallow body of water known locally as "Pigeon Lake" and "Black's Lake," which is situated in the edge of the flood-plain of the Marais des Cygnes (Osage) River about equidistant from the small towns of Fontana and La Cygne (see Map 3 and Pl. XXX, Figs. 1–2). Its area is almost twenty acres, its long axis lies approximately east and west, and its elevation is

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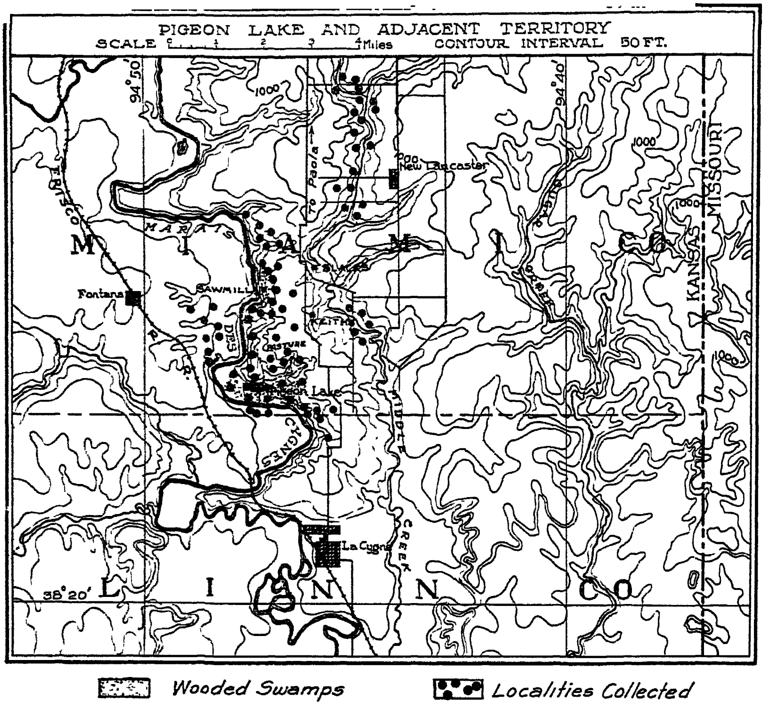
* Contribution from the Zoölogical Laboratory of the University of Michigan.

between seven and eight hundred feet. During the spring floods it is completely inundated to a depth of six or eight feet above summer water-level. A low bluff confines it on the north side, but on the east, south and west it is limited only by a slight rise



MAP 3. Map of Pigeon Lake and vicinity showing extent of area covered by collections and the approximate extent of swamp woods. Traced, with modifications, from U. S. Geol. Surv. Reconnaissance Map, Missouri-Kansas, Mound City sheet, edition of 1893, reprinted 1924

of ground in the timbered area. It is narrowly bordered on these three sides by an open marsh which is abruptly terminated by second-growth timber, gradually followed by older stands of oak, hickory, elm and walnut, with relatively little undergrowth. Throughout the spring and early summer nearly two hundred acres of this wooded lowland presents true swamp conditions, being covered with water from a few inches to a foot or two.

The west bank of the Marais des Cygnes River in this region is relatively level and is under cultivation, but the east bank is heavily wooded for a distance of more than five miles northward upstream from the lake, and for at least two miles downstream to the southeast. The width of this timbered area varies from less than one half to about three quarters of a mile and only about ten acres have been partially cleared during the past ten years. A sawmill is located in this cleared region, but it had not been in operation for some time when the observations here described were being made. To the eastward the woods give way to a gently rolling prairie some two hundred feet higher than the river. This has been utilized for stock grazing during recent years.

Both banks of Middle Creek, a tributary a few miles to the east paralleling the general course of the river, are rocky and narrowly bordered with trees. Conditions there in general resemble those near the river, although the woods are more open. A second creek, Sugar Creek, farther to the east, was not investigated.

Most of the collections and observations on which this report is chiefly based were made by the writer and associates during the spring months of 1926, 1927, 1928, and 1929. Additional specimens and information were supplied by residents of the vicinity, to whom acknowledgment is given below. Our first visit was made on May 15, 1926, at which time the region was approached from the west side of the river near Fontana. Some collecting was done in the lowlands there and in the neighborhood of Pigeon Lake; the river was crossed by boat. On the succeeding trips (except that of August 31, 1928, which was a short visit) several hours were spent each night in the marsh and swamp in collecting frogs and toads with the aid of acetylene head lamps. The night collecting was very satisfactory and successful, for amphibians were most easily taken by this method and in addition numerous snakes were secured. During the day activities were carried on along the lake shore and in the woods and uplands. After the first visit the lake was found more easily accessible from the Paola-La Cygne road on the east, from which entrance was made by way of a large prairie pasture a short distance south of the home of Mr. Paul W. Keith. Four trips ranging in duration from one to three days were made in March and April, 1927; in 1928 three days were spent there in late March (24–26) and two days in April (21–22). A brief stop was made on August 31, 1928, and a three-day visit on September 22–24 of the same year. In 1929 the region was visited once, April 6–7.

For assistance in collecting the writer is indebted to numerous friends who accompanied him during the time spent in that locality; to some who made special trips independently; and to others who sent specimens at other times. Mr. Wilbur Doudna was directly responsible for my becoming interested in the region and gave valuable assistance as a member of the party on several occasions. Messrs. Wesley Clanton, Clarence R. Collins, Hobart M. Smith, Philip D. Evans and Dr. W. B. Wilson shared in the field work at different times, and Dr. Minna E. Jewell and several members of her class in field zoölogy from the Kansas State College, Manhattan, were of great assistance on the trip of September 22–24, 1928. Mr. Alfred J. Black, owner of the land, gave us permission to use a cabin near the lake as a base of operations and was otherwise helpful in many ways. Mr. Paul W. Keith collected and sent specimens from the vicinity of Pigeon Lake and Middle Creek, and Mr. Vernen Mann secured for me a large series of copperheads and timber rattlesnakes. In connection with the entire project Mrs. Leonora K. Gloyd has given invaluable aid, and Dr. Frank N. Blanchard of the Department of Zoölogy, University of Michigan, has made helpful suggestions during the preparation of the manuscript.

HABITAT DISTRIBUTION OF SPECIES

Five fairly distinct and well-defined types of habitats were observed: (1) the lake (Pl. XXX, Figs. 1–2) and that part of its shore on the north side which is neither marsh nor swamp; (2) the marsh (Pl. XXXI, Figs. 1–2) between the open water of the lake and the woods; (3) the wooded swamp beyond the marsh (Pl. XXXII, Fig. 1); (4) the upland slopes and hillsides, more or less wooded and rocky (Pl. XXXII, Fig. 2); and (5) the upland prairie grassland. In most places in the region the transition from one habitat to another was abrupt and clearly marked, and our collections indicate a characteristic fauna for each, with relatively little overlapping, except with certain semiaquatic forms such as *Natrix sipedon transversa* and *Natrix rhombifera*, which were found in all three types of aquatic situations.

In the following list of habitats the most characteristic species in each are placed in the approximate order of their greatest abundance.

(1) The lake and lake shore:

Acris gryllus
Natrix sipedon transversa
Natrix rhombifera
Pseudemys elegans
Thamnophis sauritus proximus
Chelydra serpentina
Natrix grahamii
Triturus viridescens viridescens (immature, on shore)
Natrix sipedon sipedon

(2) The marsh:

(*a*) Deeper water near lake:
Rana catesbeiana

(*b*) Shallow water among sedges near swamp:
Hyla crucifer
Pseudacris triseriata
Hyla versicolor versicolor
Bufo americanus
Natrix sipedon transversa
Natrix rhombifera
Thamnophis sauritus proximus

(3) The wooded swamp:

Rana pipiens
Hyla versicolor versicolor
Bufo americanus
Acris gryllus
Natrix sipedon transversa
Natrix rhombifera
Chrysemys marginata bellii
Storeria dekayi
Triturus viridescens viridescens (adult)

(4) Upland slopes and hillsides:

Eumeces fasciatus
Leiolopisma laterale
Carphophis amoena vermis
Coluber constrictor flaviventris
Elaphe obsoleta obsoleta
Agkistrodon mokasen
Crotalus horridus
Storeria dekayi
Diadophis punctatus arnyi
Eumeces anthracinus
Ophisaurus ventralis
Heterodon contortrix
Storeria occipito-maculata
Lampropeltis triangulum syspila
Elaphe laeta
Ambystoma texanum (adult)
Thamnophis sirtalis parietalis

(5) The prairie grassland:

Terrapene ornata
Terrapene carolina triunguis
Thamnophis sirtalis parietalis
Pituophis sayi sayi
Tropidoclonion lineatum

The finding of *Triturus viridescens viridescens* makes a new record for the state and extends the known range of that species considerably to the westward. Another unusual occurrence is that of *Hyla crucifer*. Although the type locality of this frog is "Cantonment Leavenworth, 'Kansas'" (Wied, 1838), I know of no other records of its presence in the state.

ANNOTATED LIST OF SPECIES

The specimens secured in this region have been deposited in various museums, retained in the personal collection of the writer, or exchanged with various correspondents. The location of as large a series as is available has been given at the close of the remarks on each species. Catalog numbers have been given in practically every case. The initials O. U. M. refer to the Museum of Ottawa University, Ottawa, Kansas; U. M. M. Z., the University of Michigan Museum of Zoölogy; and H. K. G., the writer's collection. A number in parentheses following a catalog number of the U. M. M. Z., for example, "U. M. M. Z. 68389 (2)," indicates the number of individuals (when more than one) of the series entered under that number.

1. *Triturus viridescens viridescens* (Rafinesque). Newt

This species did not appear to be common in the Pigeon Lake region. The first of the two specimens secured is a terrestrial juvenile found in a piece of decaying wood among leaves, bark and débris about ten yards from the north shore of the lake, August 31, 1928. At this time no water collecting was done, but on September 22 and 23 of the same year Dr. Minna E. Jewell, several zoölogy students and myself used a thirty-foot minnow seine along nearly a hundred yards of the north shore with no success, so far as this species was concerned. Hand dip-nets were used at the water's edge and where vegetation made efficient operation of the seine impossible. The following day nearly two thirds of the entire shore-line of the lake, on the north, west and south sides, was covered by the use of hand nets without securing newts.

It was not until April 6, 1929, that an aquatic adult was obtained. This was found in the wooded swamp at the west end of the lake and was caught by hand in water a foot deep by H. M. Smith about 10:30 P.M. while collecting with the aid of an acetylene head lamp.

U. M. M. Z. 68385, 68386.

2. *Ambystoma texanum* (Matthes). Texan salamander

Two adult specimens of this salamander were secured. Both were found in wet earth beneath stones on April 6, 1929. One was near the top of the low bluff on the north side of the lake, the other at a lower level beside a small brook which contained water only during the season of spring rains.

U. M. M. Z. 68389 (2).

3. *Bufo americanus* Holbrook. Common toad

To judge from the few individuals usually singing when the region was visited, toads were by no means as common there as in other localities in adjoining territory. The species was collected in daylight among damp leaves in the woods on May 15, 1926, but during the spring of 1927, when night collecting was done on March 6, 15 and 19 and April 26, no specimens were obtained and the voice of the species was not heard. On March 24, 1928, two toads were calling about 11:00 P.M. in the marsh at the east end of the lake. These were secured, but no others were heard that night. Two were found in fairly moist woods some distance from the lake on August 31, 1928, but when the place was visited about a month later, September 22–24, none were seen. The following spring, however, a series of twenty was collected on April 7. On that date toad voices formed a conspicuous element in the amphibian chorus. Clasping pairs were among those secured, but no egg-masses were noticed.

U. M. M. Z. 66865, 66866; H. K. G. 1806–1819.

4. *Acris gryllus* (Le Conte). Cricket frog

With the possible exception of the leopard frog, *Rana pipiens*, no species was more abundant in the region than the cricket frog.

It was secured at each visit to the swamp except those of May 15, 1926, and March 6, 1927. It was collected on March 15, 1927, but was not singing. More specimens were taken on March 19 and April 26, 1927; on the latter date others were singing generally throughout the swamp and along the lake shore. In the spring of 1928 specimens were collected on March 24 and 25 and April 21. The night of April 21 was very cool and a light, intermittent rain fell most of the time from late afternoon till about 2:00 A.M. the following morning. Only a few frogs, *Hyla crucifer* and *Rana pipiens*, sang during the night. The morning brought sunshine and a marked rise in temperature and *Acris gryllus* sang at intervals throughout the day. Other collecting dates for the species were August 31, September 22 and 23, 1928, and April 6 and 7, 1929.

O. U. M. 844–852, 927–929; U. M. M. Z. 66878, 66879 (4); H. K. G. 171, 588–602, 1361–1374, 1895–1900.

5. *Pseudacris triseriata* (Wied). Swamp tree frog

Swamp tree frogs were collected in marshy spots at the edge of the lake during March and April in 1927, 1928 and 1929. This species was never present in very large numbers and its part in the frog chorus was always obscured by the jingling notes of the spring peepers and the chuckling of the leopard frogs. Unlike the cricket frog, *Acris gryllus*, it was seldom seen or heard during the day and no specimens were secured in the late summer or fall. Collecting dates for the region were March 6, 15 and 24 and April 6 and 21.

O. U. M. 853–863; U. M. M. Z. 66373, 66875, 66876; H. K. G. 1901–1908.

6. *Hyla crucifer* Wied. Spring peeper

The spring peeper was first discovered by us in the Pigeon Lake region in the late afternoon of March 15, 1927, when its chorus, mingled with the voices of hundreds of leopard frogs, produced a steady, roaring din audible for a distance of a mile and a half. Closer approach made it possible for us to distinguish between the jingling, sleigh-bell-like notes of large numbers of peepers and the deeper gutturals of the leopard frogs. The peepers were difficult to locate individually since close approach to one caused it to cease calling, although it usually kept its place until actually disturbed. Those secured on the date noted above were all males. They sang from perches upon fallen rushes and sedges a few inches above the water and appeared to be more abundant in the open marsh (Pl. XXXI, Fig. 2) than among the trees farther back from open water. Considerable variation in the pitch of their cries was noticed, and a trilled call was occasionally heard. They were still singing in vigorous choruses on March 19, but after that date their vocal activity diminished. Clasping pairs were secured on March 24, 1928, and individuals were collected on April 21 and September 23 of the same year. An additional series was obtained on April 6, 1929.

O. U. M. 814–818, 833–843; U. M. M. Z. 66871 (3), 66872 (3); H. K. G. 576–582, 1914–1926.

7. *Hyla versicolor versicolor* (Le Conte). Common tree frog

Our first experiences with tree frogs of this species in the vicinity of Pigeon Lake occurred when Mr. Wilbur Doudna and I made a trip to the lake on April 26, 1927. The night was extremely dark and the air warm and humid, although no storm appeared imminent. Between 8:00 and 9:00 P.M. widely scattered tree frogs were singing at the edge of the open water near the northwest end of the lake. Their calls varied considerably in pitch, with an occasional cry so different as to lead one to suspect the presence of another species. Three of these unusual voices were carefully traced until the frog responsible for the song was definitely located. In each case it proved to be the ordinary form.

After nearly two hours of collecting in the western extremity of the lake, we had traversed an irregular semicircle and had reached the south side, where the steady roar of a different frog chorus first became distinguishable from the sounds produced by scattered individuals closer at hand. It appeared to come from the depths of the swamp woods between the lake and the river and somewhat downstream toward the east. After allowance had been made for the deceptiveness of distances under such conditions, the location of this breeding group was later estimated as slightly less than a half mile from the lake and approximately the same distance from the river.

When we reached the spot, we found ourselves in the midst of an amazingly large aggregation of breeding tree frogs concentrated in a small area to all appearances no different from any other acre of wooded swamp near by. The water among the large trees ranged between six inches and two feet in depth, probably much deeper than usual, since there was evidence of recent heavy rains and flooding from the river. There was practically no undergrowth of small trees or shrublike plants, but fallen trees and brushwood from dead branches were plentiful in the water.

It was impossible to estimate the number of singing individuals with any approach to accuracy, but it was very large. The noise from the undiminished chorus was deafening and single cries, even from individuals but a few feet distant from us, were practically indistinguishable. Our communications to each other had to be shouted although we were almost close enough together to touch hands.

Singing males seemed to be taking advantage of any convenient location, calling from the water, from the tops of wet logs, from perches in partly submerged fallen branches, and from bases of tree trunks a few inches above the water. Wherever our lights turned, from two to fifteen individuals were visible within their range. Females were less conspicuous, but they seemed to occur in each of the locations mentioned. Numerous mating pairs were found in the water and now and then a male embracing a female was carried by her from the water to a floating stick or fallen log. Our presence produced no disturbance of their activities and nothing seemed to be capable of reducing the vigor of their cries. Singing males picked up and allowed to sit in the palm of the hand continued calling with unabated zeal. Their notes were repeated with greater energy and at more rapid intervals than those of the frogs singing at the edge of the open lake earlier in the evening.

This species was not collected when we were in the region during March and April, 1928. The season that year was less advanced and the temperature was lower. Presumably the frogs had not begun to breed. A few specimens were taken, however, on September 23, 1928, and April 6, 1929.

O. U. M. 930–947, 974–980; H. K. G. 1375, 1894.

8. *Rana catesbeiana* Shaw. Bullfrog

The bullfrog was fairly abundant and was frequently collected. It kept to the deeper water at the edge of the marsh (Pl. XXXI, Fig. 1) and was never found in the wooded swamp farther from the lake. On our early spring visits to the region (March 6, 15 and 19) we noticed that adult bullfrogs had not yet appeared, although small, immature individuals were collected on March 15, 1927. The earliest singing date noted was on March 24, 1928. The species was either heard or secured on each of the following dates: April 26, 1927; March 24, April 21, September 22, 1928; April 7, 1929.

O. U. M. 822, 823; U. M. M. Z. 66831–66837, 66839, 66841.

9. *Rana pipiens* Schreber. Leopard frog

The leopard frog was by far the most abundant species of amphibian in the swamp. None of our specimens were collected in the marsh and only a very few along the lake shore. In the 1927 season this species seemed to be at the height of breeding activity on March 15. Very large numbers were singing in the wooded swamp areas on three sides of the lake. In many small open spaces among the trees (Pl. XXXII, Fig. 1) several hundred breeding individuals were gathered together. Some of these open spaces observed in detail were roughly circular in outline and about ten or twelve feet in diameter. At a distance of thirty yards such areas appeared closely stippled with sparklike luminous dots as the eyes of the singing frogs reflected the rays from our head lamps. When we approached, even though slowly and carefully, the eyes disappeared a few at a time as the frogs submerged, for they appeared to detect disturbances in the water at a much greater distance than do toads, bullfrogs, and some other amphibians. Some of the breeding grounds were already covered with egg-masses. By counting those in about half of such an area, the total number of egg-masses was estimated at one hundred and fifty. In spite of the thousands of eggs already laid, the breeding activity appeared undiminished, for clasping pairs were extremely common and many were secured.

Numerous individuals were singing in the swamp on each date on which we visited the region during March and April. A few were collected on May 15, 1926, and September 22–23, 1928.

The majority of the leopard frogs breeding in that lowland, river-bottom swamp appeared in general to be smaller, and more brilliantly green, and to have relatively smaller spots than those breeding in upland ponds and streams in other eastern Kansas localities during the same seasons.

O. U. M. 824–832; U. M. M. Z. 66884 (6); H. K. G. 603–605, 615, 617.

10. *Ophisaurus ventralis* (Linn.). "Glass-snake"; "joint-snake"

Only one specimen of this species of legless lizard was secured. It was collected on April 21, 1928, by Clarence R. Collins, in a pile of leaves on the lower slope of the bluff north of the lake (Pl. XXXII, Fig. 2). It sought to escape by backing into a hole in the soft ground.

U. M. M. Z. 66930.

11. *Leiolopisma laterale* (Say). Ground lizard

This little skink was most abundant on the wood hills of the vicinity after the first of April. It was found under stones, logs and bark, and was often seen in the open among dead leaves in the higher areas near the lake and along Middle Creek. In the autumn it appeared to be more secretive and was rarely seen. Four were taken on August 31, 1928, but none were secured on September 22–24 of the same year.

O. U. M. 262, 263; U. M. M. Z. 66932 (3), 66934 (2), 66935 (2); H. K. G. 1075, 1076, 1516–1521.

12. *Eumeces anthracinus* (Baird). Coal skink

A total of nine specimens of this comparatively rare species was obtained. None were found in localities other than the hillside on the north shore of the lake (Pl. XXXII, Fig. 2) and all were collected by lifting loose stones and raking among mats of fallen leaves. Collecting dates for this species were May 15, 1926; March 19, 1927; March 25 and August 31, 1928; April 6, 1929.

O. U. M. 201; U. M. M. Z. 65450, 68451, 68452 (5).

13. *Eumeces fasciatus* (Linn.). Five-lined skink

In wooded areas of sufficient elevation to be out of the river flood-plain this lizard was abundant. It was found beneath stones, in crevices, under bark and leaves and in trees; and occurred in the higher woods near the lake, along the west bank of Middle Creek, near the river north of the sawmill and on the west bank of the river near Fontana. Mr. Paul Keith obtained a considerable number for us on April 22, 1928, from a lower point on Middle Creek near the Miami-Linn county line.

O. U. M. 224, 225; U. M. M. Z. 66922 (3), 66923 (2); H. K. G. 305, 306, 1001, 1522–1548.

A more or less constant but unsuccessful search was made in the upland areas of this region for the sonoran skink, *Eumeces obsoletus* (Baird & Girard). It is known to occur commonly in Franklin and Anderson counties, which respectively adjoin Miami and Linn counties on the west, and in Bourbon County, next to Linn on the south. Its apparent absence may be due to its habit of frequenting higher country than that of the vicinity of Pigeon Lake.

14. *Carphophis amoena vermis* (Kennicott). Western worm snake

Worm snakes were frequently collected on the hillside north of the lake, along the low bluffs of Middle Creek, and in the more open country north of the sawmill. All specimens were found in fairly moist places beneath stones or among closely packed leaves. Collecting dates were May 15, 1926; March 25, April 21, 22, August 31 and September 23, 1928; April 6, 1929.

O. U. M. 391, 392; U. M. M. Z. 66972 (3), 66973 (3); H. K. G. 436–438, 1048, 2265–2278.

15. *Diadophis punctatus arnyi* (Kennicott). Ring-neck snake

The ring-neck snake was not common near Pigeon Lake. Two were found beneath stones on an open hillside near Middle Creek, September 23, 1928. The following spring, April 6, 1929, two more were obtained; one adult beneath a stone in the same locality, and one young, probably of the previous year's brood, under a small stone in the pasture between the La Cygne road and the lake.

H. K. G. 1444, 1445.

16. *Heterodon contortrix* (Linn.). Hog-nosed snake; "spreading adder"

No hog-nosed snakes were secured on any of our regular collecting trips, but one was caught on May 14, 1928, by Mr. Paul W. Keith on his farm between Middle Creek and Pigeon Lake. Since it was a gravid female it was kept under observation in the laboratory for the next two months. During this period it fed upon medium-sized toads, *Bufo woodhousii* Girard, but refused to eat frogs and mice.

One sterile egg was expelled on June 23. Nine eggs, of which one proved to be abnormal, were deposited on June 26. On this date the female was observed at 8:30 A.M., at which time two good eggs and the second sterile one had been deposited. Six more normal eggs were laid at intervals ranging from ten to sixty minutes, the last being deposited between 12:15 and 1:00 P.M. In the two cases in which the process was observed, about one minute was required for the act of expulsion. The freshly laid eggs were soft, moist and almost transparent. After exposure to the air for about ten minutes the tough outer membranes became opaque and cream white.

The eight eggs were placed in a metal container with a mixture of finely crumbled sphagnum and rotting wood and kept slightly moist by an occasional sprinkling with water. All the eggs hatched on August 23 and 24, within sixty days after being laid. At 8:00 A.M., August 23, three had been slit for a short distance by the egg tooth of the young snake. One emerged about noon. During the afternoon three more were cut and two young emerged between 8:00 and 10:30 P.M. All were hatched the following morning. Three of the young shed a very fine, thin layer of epidermis three days after hatching; the others moulted during the following twenty-four hours.

At the age of two days the young snakes were measured and weighed; the results follow:

	Total length	*Tail length*	*Weight*
♀	190 mm.	29 mm.	6.0 gm.
♀	197	31	6.6
♀	183	27	5.0
♀	202	30	6.6
♀	203	32	6.0
♂	168	29	4.6
♂	192	34	5.9
♂	200	34	6.4

U. M. M. Z. 66869, 66968 (8).

17. *Coluber constrictor flaviventris* (Say). Blue racer

The blue racer was a common snake in the higher areas near the lake. An extremely dark-colored specimen, more slate gray than bluish green, was discovered inside a rotten log near the lake on April 21, 1928. Others of normal coloration were collected on a hillside near Middle Creek the same day and two more were secured on September 23 of the same year. In 1929 several were taken during the month of April. Mr. Vernen Mann saw one of these kill and eat a copperhead (*Agkistrodon mokasen* Beauvois). According to his account of the incident, he came upon the two snakes just after the racer had made its capture and was chewing the head and neck of its victim, which was thrashing about in violent efforts to free itself. He observed the entire swallowing process, which lasted more than an hour. Mr. Mann also reported that a lizard (probably *Eumeces fasciatus*), on a rock about six feet from the snakes, was another interested witness and displayed great curiosity and animation, fleeing when a sudden movement of a snake occurred, but returning at once to its vantage point on the rock over the edge of which it peered intently as if fascinated by the spectacle. The blue racer was sent to me. Three days after its ophidian repast it was killed and the copperhead removed from its stomach. The anterior third of the latter was fairly well digested.

U. M. M. Z. 67055, 67053; H. K. G. 552, 1448, 1494, 1495, 1636, 1735.

18. *Elaphe laeta* (Baird and Girard). Rat snake

One small individual of this species was obtained. It was beneath a stone in open woods a short distance north of the sawmill, April 21, 1928.

H. K. G. 440.

19. *Elaphe obsoleta obsoleta* (Say). Pilot black snake

Pilot blacksnakes were taken in the woods near the lake, on the hillsides above the sawmill and among rocks along Middle Creek. Nearly all were on higher ground, but one was beside a small rain pool with a *Natrix sipedon transversa* quite close to the lake. One was found in a cavity at the base of a large oak on the north shore of the lake (this tree is shown in Pl. XXXII, Fig. 2). Another was crossing the trail along this same hillside. It "froze" rigidly when we approached, with the curves of its body pressing closely into the irregularities of the ground. Collecting dates were May 15, 1926; March 24, 25, September 23, 1928; April 6, 1929.

O. U. M. 409; U. M. M. Z. 67046; H. K. G. 1608, 2112.

20. *Pituophis sayi sayi* (Schlegel). Prairie bull snake

A bull snake was collected on May 1, 1928, at the edge of the prairie about two hundred yards northeast of the lake by Mr. Wilbur Doudna.

U. M. M. Z. 66950.

21. *Lampropeltis triangulum syspila* (Cope). Red king snake

A small king snake of this form was taken from moist earth beneath a stone in open woods a half mile north of the sawmill, April 21, 1928. Another was found in a similar habitat on Middle Creek, April 6, 1929.

The color pattern of both these individuals is typical of the form *syspila* as defined by Blanchard (1921).

H. K. G. 430, 2354.

22. *Natrix grahamii* (Baird and Girard). Graham's water snake

This species is represented by but one small individual found on August 31, 1928, coiled in a slight depression in the top of a rotting log near the shore of the lake.

U. M. M. Z. 66989.

23. *Natrix rhombifera* (Hallowell). Diamond-backed water snake

Numerous individuals of this species were found in the open along the lake shore, in the marsh and swamp at night, and beneath logs, bark and débris in the vicinity of the lake. Collecting dates were March 24, 25, April 21, September 23, 1928; April 6, 1929.

U. M. M. Z. 67000, 67010; H. K. G. 1438, 1439.

24. *Natrix sipedon sipedon* (Linn.). Common water snake

This water snake was not often found in the vicinity of the lake and marsh. Two were secured on March 24, 1928, under a board at the edge of the lake. A third specimen was found on August 31 of the same year beneath a flat-bottomed boat drawn up on the lake shore.

Since in eastern Kansas this species seems to frequent running water rather than marshy habitats, it is probable that a more careful search along the streams of this vicinity would prove it to be fairly abundant.

U. M. M. Z. 67016 (2); H. K. G. 1079.

25. *Natrix sipedon transversa* (Hallowell). Blotched water snake

Our collections indicate that this was the most abundant water snake of the marsh and swamp habitats. It was encountered both along the lake shore and in the heart of the swamp. On the morning of March 24, 1928, after a cold night, several large specimens were coiled in the sun rather close together on a narrow strip of flat ground on the north side of the lake.

A female (U. M. M. Z. 66997) collected on August 31, 1928, gave birth to twenty-one young on September 14. The young were undergoing their first ecdysis at the age of three days.

Fusion of the lateral with the dorsal blotches in the neck region so as to form the complete cross-band pattern characteristic of the subspecies *sipedon* occurs in eleven individuals of this brood (U. M. M. Z. 66998). In the remaining ten the lateral blotches alternate with the dorsal ones anteriorly as far as the head, the typical pattern of the subspecies *transversa.*

U. M. M. Z. 66997, 66998 (21); H. K. G. 1242, 1335, 1447, 2109.

26. *Storeria dekayi* (Holbrook). De Kay's snake

A snake of this species collected at night on March 15, 1927, was swimming in water twelve inches deep among the trees of the swamp. Another was found on April 21, 1928, beneath a log in woods about a mile north of the sawmill. Two were found among chips and dead leaves on September 23, 1928, and still another beneath a stone on April 6, 1929.

O. U. M. 874; U. M. M. Z. 66987 (2); H. K. G. 431, 1446.

27. *Storeria occipito-maculata* (Storer). Red-bellied snake

Only two red-bellied snakes were obtained; a small specimen among leaves on moist ground in heavily wooded region near the river, May 15, 1926, and an adult found on March 24, 1928, beneath a board in the vicinity of an old cabin on the north shore of the lake.

H. K. G. 423.

28. *Tropidoclonion lineatum* (Hallowell). Line snake

A single specimen was taken from beneath a stone in a shallow ravine of the pasture above the lake and swamp.

H. K. G. 1449.

29. *Thamnophis sauritus proximus* (Say). Western ribbon snake

The western form of the ribbon snake occurred along the lake shore and at the edge of the marsh. Three were taken near the lake, April 26, 1927; another in approximately·the same locality, March 24, 1928; one beneath an old boat on the north shore of the lake, August 31, 1928; and two at the edge of the swamp at the west end of the lake, April 6, 1929.

A female, 625 mm. long, collected on August 31, 1928, contained six young which appeared to be almost ready for birth.

O. U. M. 948; U. M. M. Z. 67035; H. K. G. 1081, 1442, 1443.

30. *Thamnophis sirtalis parietalis* (Say). Red-barred garter snake

The red-barred garter snake is represented by but two specimens. One was taken in open woods north of the sawmill, April 21, 1928, and the other found beneath a stone in a ravine of the pasture, April 6, 1929.

H. K. G. 432, 1437.

31. *Agkistrodon mokasen* Beauvois. Copperhead

Copperheads were fairly abundant in the rocky ledges on the east bank of the Marais des Cygnes River and on Middle Creek. Near the sawmill ten were found on April 21, 1928, at various intervals at depths of about twenty inches among loose rocks on a rather steep slope. The weather had been cool for the preceding two days and the snakes were quite sluggish. Mr. P. D. Evans and I secured seven, September 23, 1928, along the west bank of Middle Creek. Two were found beneath a stone, but the others occurred singly in crevices and on sunny ledges. In 1929 a male and a female were found, April 6, under a large stone southeast of the lake close to the Miami-Linn county line.

Mr. Vernen Mann had considerable success in collecting these snakes. In various rocky ledges southeast of the lake, both in Miami and Linn counties, he secured for me a total of over a hundred and twenty-five during the month of April, 1929. In the material which he collected the ratio of males to females was approximately two to one. Although unable to find copperheads during the summer months, he collected a few more in these same localities in September and October. A report of studies on the breeding habits of this species has been given elsewhere (Gloyd, 1932).

U. M. M. Z. 68427, 68428; H. K. G. a large series.

32. *Crotalus horridus* (Linn.). Timber rattlesnake

No rattlesnakes were collected by any of our parties although they formed one of the major objectives of our search. Through the kindness of Mr. Paul W. Keith we were able to obtain two specimens taken on Middle Creek, one on April 30 and one on June 11, 1928. Mr. Vernen Mann secured two a few miles north of La Cygne during late August, 1928, and the following year sent me twelve collected during April and nine secured in September and October, in rocky bluffs southeast of Pigeon Lake, the locality in which he found copperheads most numerous.

Mr. Alfred J. Black told us that frequently rattlesnakes wander up to his dooryard from Middle Creek, and that on one occasion he found two coiled upon his cellar door. Farmers near Fontana on the west side of the river asserted that during the summer rattlesnakes come across the river from the bluffs on the east bank into the low fields of the west side, and that they are often seen swimming the river in the fall as they return, presumably to crevices in the rocks for winter.

U. M. M. Z. 68467–68476; H. K. G. 1493, 1671, 1693, 2296, 2297, 2331, 2332, 2349, 2350, 2352, 2361, 2362.

33. *Chelydra serpentina* (Linn.). Snapping turtle

One snapping turtle was collected in the shallow water of the east end of the lake, April 6, 1929, but the specimen is not now available.

PLATE XXXII

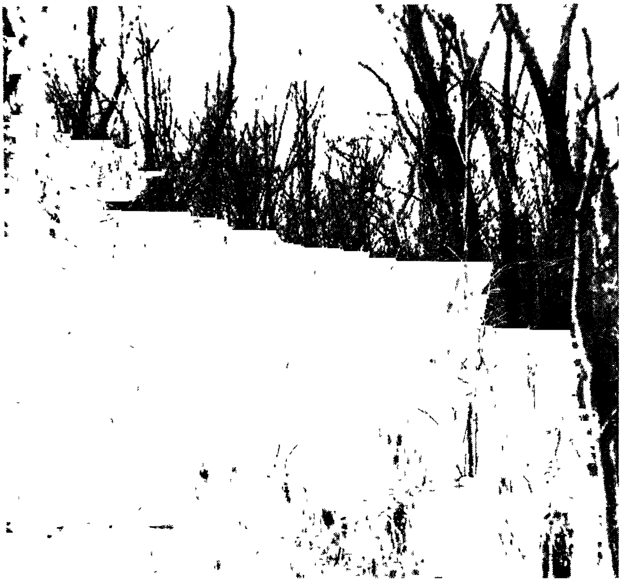


FIG. 1. A relatively open area in Pigeon Lake swamp. Water from a few inches to two feet deep. Habitat of *Rana pipiens* and *Hyla versicolor versicolor*. Photographed April 22, 1922

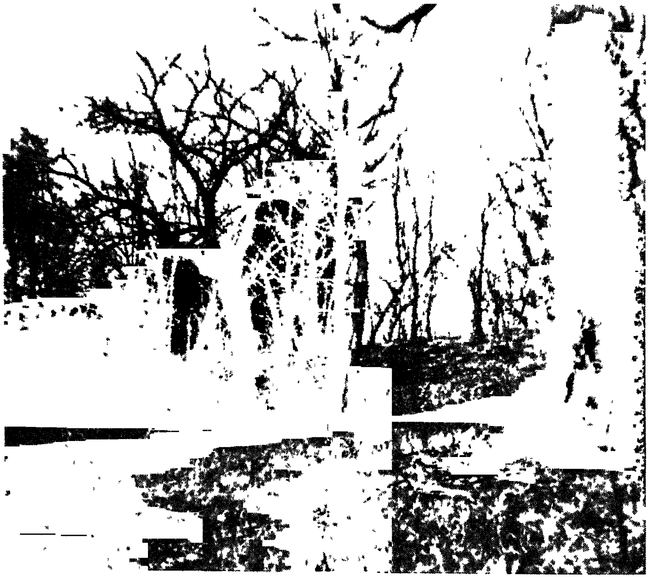


FIG. 2. Low bluff on north shore of Pigeon Lake. Loose rocks, decaying leaves and bark. Habitat of *Eumeces fasciatus*, *Eumeces anthracinus*, *Leiolopisma laterale*, *Coluber constrictor flaviventris*, *Elaphe obsoleta obsoleta* and numerous other species. Photographed April 22, 1928

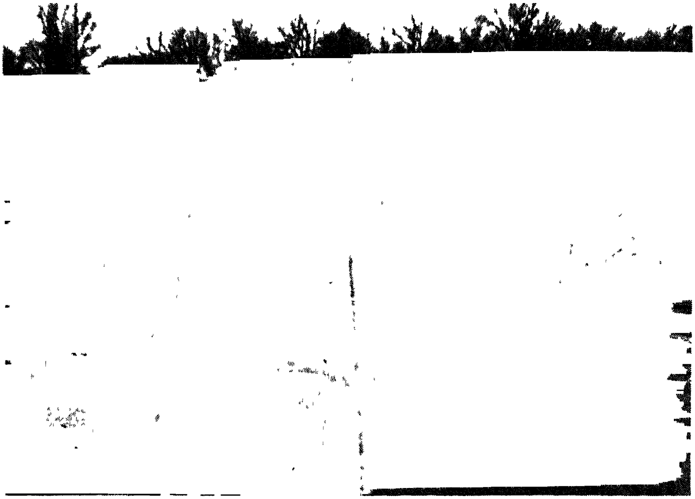


FIG. 1. Outer edge of marsh, southeast edge of Pigeon Lake; deeper water. Habitat of *Rana catesbeiana*. Photographed April 22, 1928

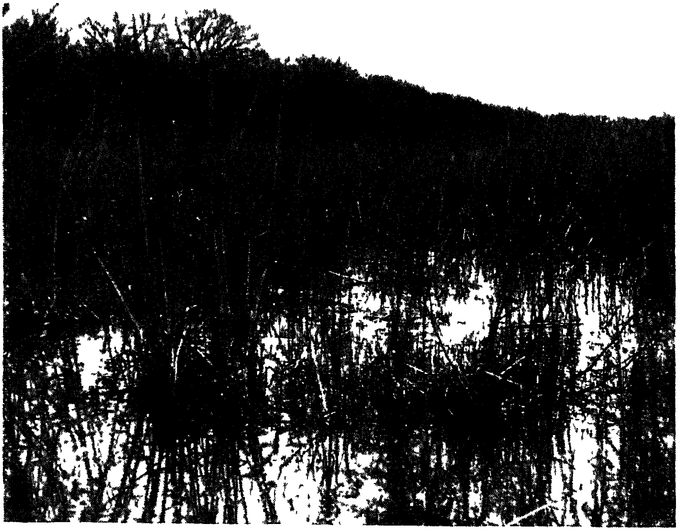


FIG. 2. Marsh at southeast edge of Pigeon Lake. Habitat of *Hyla crucifer*, *Pseudacris triseriata* and *Bufo americanus*. Photographed April 22, 1928

PLATE XXX

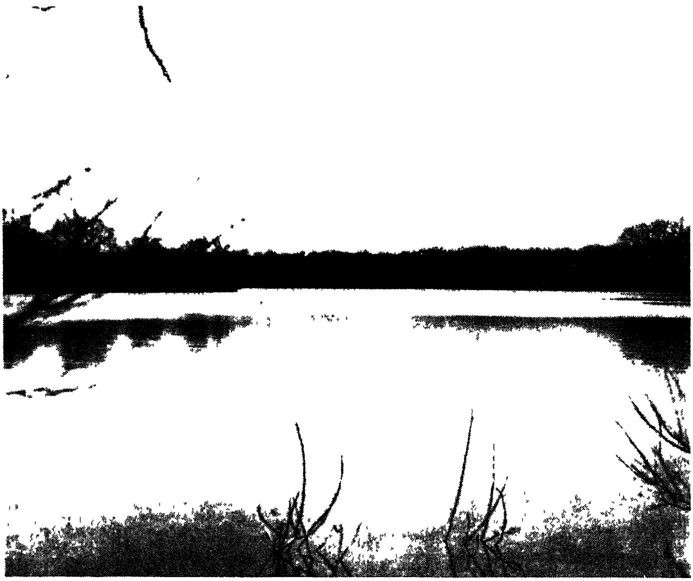


FIG. 1. Pigeon Lake from the northeast; swamp woods on opposite shore. Photographed April 22, 1928

FIG. 2. Pigeon Lake from the north, showing marsh and wooded swamp of opposite shore. Photographed April 22, 1928

34. *Terrapene carolina triunguis* (Agassiz). Three-toed box turtle

A single individual of this form was found partially concealed under the edge of a stone in the pasture, April 6, 1929. This and two of the following species were sent to a correspondent.

35. *Terrapene ornata* (Agassiz). Western box turtle

Several specimens were secured in the pasture north of the lake. One was collected on August 31, 1928, two on September 22, 1929, and a fourth was found on April 7, 1929.

H. K. G. 1571.

36. *Chrysemys marginata bellii* (Gray). Bell's painted turtle

Two painted turtles of this subspecies collected in the swamp on May 15, 1926, were sent to Mr. Percy Viosca, Jr., of the Louisiana State Museum.

37. *Pseudemys elegans* (Wied). Red-eared turtle

One was obtained by the use of a large seine in the lake, March 25, 1928, and two others were collected with hand nets at the edge of the water, September 23, 1928.

H. K. G. 1258.

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OBSERVATIONS ON THE BREEDING BEHAVIOR AND HABITATS OF FISHES IN SOUTHERN MICHIGAN

THOMAS L. HANKINSON

IN THE spring of 1930 conditions were found to be ideal for the study of the breeding of creek fish in a portion of the Saline River beginning at the tourist camp just west of Saline, Washtenaw County, Michigan, and extending about a half-mile downstream.

Information on the breeding activities and habitats of the fishes of southern Michigan is being obtained in the course of studies of the ecology of aquatic animals in this region by the writer and his students; and it is planned to publish a series of papers giving data on the breeding of the fishes found there and supplementing the abundant, valuable information obtained by the long and patient studies of Dr. Jacob Reighard, who has published papers on *Amia* (1903), the horned dace (1910) and suckers (1920).

The Saline River arises from a number of small streams in the region south of Ann Arbor and flows southerly, entering the Raisin River a few miles below Dundee in Monroe County, Michigan. Near Saline it is close to the headwaters and is more like a creek than a river. At the time it was visited its average width was about twenty feet, but it varied from a few feet to forty. Like typical creeks, it formed a series of pools and intervening shallows. There were stretches of riffles below most of the pools, where it was so shallow that the water broke over the small stones. In the deeper portions the bottom was hard, of intermixed sand and clay. Boulders were located here and there, and in places there was an abundance of rocks or cobbles. Plate XXXIII, Figure 1, shows a typical pool above a narrows, with a stretch of riffles at its lower end.

The stream winds through a scantily wooded region. Its banks vary in height and slope; in places the current has cut the shore and formed low, vertical cliffs that arise about six feet above the surface of the water (Pl. XXXIV, Fig. 1). The root systems of large trees along the bank had retarded the erosion of the shore in a number of places and diverted the current downward, so that it washed away bottom material and increased the depth. The deepest pools and the best hiding places for the fish were formed in this way. The root masses, freed of soil by the water, gave still further seclusion. It was in such places that the larger fish were found, and to them they retreated from spawning beds in shallow water on being disturbed. The most extensive breeding areas, with the most fish upon them, were always in the lower portions of pools that offered the best protection.

There was a scarcity of fish predators at the time of our observations about the breeding places. A few herons were noted, among them the great blue (*Ardea herodius*) and the green (*Butorides virescens*). In spite of the accessibility of the many small fish, no kingfishers were seen on our visits. The proximity of the town and the camp (although there were rarely many campers) probably explained the scarcity of wary fish-eating animals and helped to create favorable conditions for the study of breeding fish. There was practically no inducement for people to disturb the fish, since there were not enough large ones to attract anglers and it was too early in the season to catch minnows for bait. Another feature favorable for our studies was the absence of pasturing animals; in wading these would have scattered schools of spawning fish and trampled their nests.

Eleven visits were made to this part of the stream from May 8 to June 14 in the spring of 1930. During this time the weather was ideal for the studies. There were no decided changes in temperature, and very little rain fell — none sufficient to swell the stream or make it turbid. The sun shone most of the time; and the wind was not strong enough to ruffle the water and prevent observations. The following table gives more detailed information of conditions at times of visits.

TABLE I

CONDITIONS OF STREAM AT TIMES OF VISITS

Time of visit		Thermometer readings (Degrees Centigrade)	
Date	Hours	Air	Water
May			
8	3:00–4:00 P.M. 7:00 P.M.	26 18	24.5 23
10	9:00 A.M.–12:00 M.	25	22
11	1:00–6:00 P.M.	21	22
14	10:00 A.M.–6:00 P.M.	14 and 15	18 and 19 (A.M. and P.M.)
16	4:00–5:00 P.M.	13	19
23	2:00–4:00 P.M.	25	26
30	10:00 A.M.–1:00 P.M.	15	14.5
June			
4	10:00 A.M.–2:30 P.M.	21	26
14	3:00–6:00 P.M.	27	29

Just above nearly every piece of riffles, in the lower parts of pools in water about six to eighteen inches deep, there were low, roundish, conical piles of cleaned stones, ordinarily a peck or more. Such accumulations are commonly seen in our larger creeks and small rivers in spring. People sometimes marvel how they came into existence, but students of fish know that they are nests of certain large creek minnows of the genus *Nocomis,* and that they are built of stones brought from the vicinity by the males, which carry them in their mouths and drop them to form heaps of cleaned gravel, which harbor the eggs laid by the female during the spawning act. This act occurs at intervals over the nest. Formerly these piles of stone were thought to be the work of one species of fish called the hornyhead or river chub (*Hybopsis kentuckiensis*), but through the studies of Dr. Carl Hubbs it was learned that there are two species, which he has designated as the hornyhead (*Nocomis biguttatus*) and the crested chub (*N. micropogon*). The latter becomes the larger, reaching in our streams a length of eight inches, whereas the former scarcely exceeds six inches. There are other differences, for example, the arrangement of the nuptial tubercles in the breeding male. Detailed descriptions are given by Hubbs (1926). The nests of the two forms cannot be distinguished except through seeing the fish at work, or by noting the sizes of the stones. Where the stones are large, the inference is safe, according to Dr. Hubbs, that the work could have been done only by big males of the larger species. Both species of *Nocomis* were found in this part of the Saline River, near Saline. The hornyhead was much more abundant; and it is evident that both species were nesting there. Only twice did the writer see males building by carrying stones, and these were hornyheads. In 1919, in the Galien River, Berrien County, Michigan, he saw nearly the whole process of nest construction by the hornyhead (Hankinson, 1920, p. 9, as *Hybopsis kentuckiensis*). Greeley (1929, p. 170) made similar observations on the nesting of the crested chub in western New York.

As many as nine nests of *Nocomis* were found about a single stretch of riffles, in the Saline River, at the place shown in Plate XXXIII, Figure 2. The following measurements were made on May 16 and 25, 1930.

TABLE II

MEASUREMENTS OF *NOCOMIS* NESTS

Depth of water, in inches, at the location of *Nocomis* nests	Dimensions of *Nocomis* nests, in inches	Height, in inches, of *Nocomis* nests above general level of stream bottom about nest
13	17 × 22 × 4	2
23	18 × 20 × 2	1.5
13	36 × 36 × 6	3
10	14 × 17 × 3	2
10	30 × 29 × 4.5	2
12	24 × 20 × 3	2
14	20 × 36 × 3	2
10	17 × 36 × 3	2

It will be noted from the table that the nests measured were always embedded in the bottom material, which made the piles somewhat convex below as well as above. The term "lenticular" has been applied by Dr. Hubbs to the form of these nests. The fish may choose a slight depression to which to bring stones, or possibly its initial work in nest-building may be the carrying away of objects on the bottom to make a slight hollow, and perhaps loose soil is removed by sweeping, as is done by sunfishes.

An important result of the observations on the breeding fish in this half mile of the Saline River was the discovery that the gravel piles built by the males of *Nocomis* produced optimum conditions for the breeding of three other species of minnows abundant in this part of the stream. These are the common shiner (*Notropis cornutus* of both subspecies, *frontalis* and *chrysocephalus*), the rosy-faced shiner (*Notropis rubellus*) and the red-bellied dace (*Chrosomus erythrogaster*). None of these species was noted spawning elsewhere than over the stone heaps made by *Nocomis*.

A spawning group of common shiners was seen on practically every one of these stone piles, and such a group was dominated by a single large male, busy keeping away intruding fish and displaying his red-flushed sides and other features of attire peculiar to the sex at the breeding time (Forbes and Richardson, 1909, colored plate facing p. 147). Schooling closely around this male there were usually many smaller and unadorned common shiners, most of which were mature females; they were identified easily by their egg-swollen abdomens. The large male was frequently approached by others, which he fought away, except when the newcomer was larger or the better fighter, as was observed a number of times. In such a case the intruder drove the fish away and took possession of the holding himself. Where the two fish seemed equally formidable, they paraded side by side in a zigzag manner upstream, often for several feet. Then they separated, apparently without any surrender of the holding. Reighard (1910, p. 1128) describes behavior like this by breeding male creek chubs and calls it "ceremonial behavior."

Along with attempts to maintain the holding, the male fish performed important duties. Fishes of several species continually tried to get at the eggs scattered in the superficial gravel of the nest or to spawn there. Efforts to rid the nest of these pests were continually made by the guarding shiner, but with poor success. It was noted that small fishes with protective markings, such as female and immature male rainbow darters and young hammerhead suckers, were little disturbed in their encroachments. The spawning of common shiners, which was noted on a number of occasions, was accomplished in a fraction of a second. Preliminary to the act the male would corral the females toward the middle of the nest, and then he would throw his body into a curve, on the inside of which the female was held; sometimes she was held on the right and sometimes on the left side of the male and always with the head pointing upward. The quickness of the act and the accompanying disturbance of the surface of the water made it impossible to observe details, but, so far as could be discerned, the spawning act was like that of the creek chub as observed by Reighard (1910, p. 1130).

It was very evident that these shiners and other fishes spawning with them had become habituated to the presence of people, as they had to the swallows that nested in the banks of the stream and were continually dipping down into the water over the fish in capturing insects from the surface of the water. Reighard (1910, p. 114) has noted a comparative fearlessness shown by suckers and creek chubs when their spawning areas are near bridges and other places where people and vehicles move frequently in plain view.

Late in the spawning season of the common shiner, in June, 1930, only small males were found with holdings. This may have been due to the occupation of the spawning beds by the larger and more formidable males earlier in the season, thus forcing the small ones to wait, or possibly it was because the small males matured later than the large ones, but the first explanation seems most likely, for I have seen very small males spawning elsewhere early in the season.

In this stretch of the Saline River, in May and June, 1930, no common shiners were found with holdings except over the stony heaps made by *Nocomis*. This is not a universal condition, however, for common shiners are abundant and are generally distributed in many streams where there are no *Nocomis*. According to my observations, they sometimes use the gravelly ridges constructed as nests by the creek chub (*Semotilus*). Although common shiners show preferences for the structures built by other fishes as places to deposit their eggs, they will use patches of water-cleaned gravel and in all probability with success, for they often occur in creeks where there are no stone-carrying species.

The writer has found *Nocomis* nests being used as holdings for spawning purposes by common shiners in a few other regions in Michigan and in western New York. Greeley (1929, p. 172) made similar observations in this New York locality.

The rosy-faced shiners accompanied nearly every group of spawning common shiners and received protection from the male of this species, which had established the holding. Often fifty or more males of the former were present and occupied a stratum just above the group of common shiners and gave prominence to the whole association by the flashings of their red-flushed bodies. Each fish was about two and one-half inches long and very slender (Forbes and Richardson, 1909, p. 154). With these males there were a few females, and they, without the suffusion of red, were very inconspicuous. Spawning could be seen among these rosy-faced minnows, since it always took place high above the other fish of the aggregation and several inches above the gravel. The males would collide with the females, striking them on or near the head with their roughened snouts, and the two would contort themselves in a way that suggested spawning. Dr. Hubbs has seen in the Huron River a behavior of this species similar to that noted here.

The brilliantly colored males of the red-bellied dace seemed always present, and they, too, were spawning, but the act could not be distinctly seen, for they kept low over the gravel. Collections showed gravid females with the breeding males; they were taken on May 10 and 11, 1930. The males were highly colored, with the lower body parts of brilliant red. The colors were those of the plate shown by Forbes and Richardson (1909, facing p. 112).

Other species associated with the common shiners over the *Nocomis* nests and either spawning or searching for eggs as food were: stone-roller (*Campostoma anomalum*), blunt-nosed minnow (*Hyborhynchus notatus*), hammerhead sucker (*Hypentelium nigricans*), rainbow darter (*Poecilichthys caeruleus*), green-sided darter (*Etheostoma blennoides*) and Johnny darter (*Boleosoma nigrum nigrum*).

That a number of species were depositing eggs in the gravel was made evident by the finding of eggs of several different sizes in handfuls of gravel picked up. In addition to the species of fishes just listed, *Nocomis* must have spawned over its own nests, but observations did not reveal their spawning; and only on a few occasions were members of this genus seen about the stone piles. Those seen were breeding males. The ones identified with certainty were hornyheads (*Nocomis biguttatus*).

Time did not permit making a detailed study of the interrelations of the fishes that composed what might be called the common shiner spawning association, established primarily by the work of *Nocomis*, but such a study would give results of considerable ecological interest and of some economic bearing, since the principal fishes involved, the common shiner, the hornyhead and the crested chub, are all of considerable value as bait. By establishing or perpetuating these fish associations in streams large numbers of good bait minnows may be had at any time.

One interesting interrelation between the hornyhead and the common shiner which was observed by Dr. Hubbs and the writer was interpreted by Dr. Hubbs as a possible case of commensalism. I noticed a similar instance in another part of the stream. The male hornyhead was busy carrying stones and the large shiner was chasing away intruders, but never did they interfere with each other; both were working together and were mutually helpful. On occasion, the hornyhead also kept away trespassing fish. An instance of this was noted when a large hammerhead sucker about fifteen inches long crept slowly upon the nest; its protective markings seemed to conceal it from the guarding fish for a time, but suddenly it was noticed by the male hornyhead while performing his task of stone-carrying. At once he gave the sucker a blow on the side of the head with his tubercle-roughened snout and with sufficient force to send it several inches over to one side.

A few more blows started an upstream retreat, with the hornyhead following for a dozen or more feet. The encounter showed the effectiveness of the nuptial tubercles as organs of offense. The hornyhead was probably not a quarter of the size of the sucker.

Large males of the black-sided darter (*Hadropterus maculatus*) were frequently seen in the Saline River at the time of the observations in May, 1930. Collections made at this time revealed that the males were much larger than the females, being about four inches in length, and more highly pigmented and hence darker than the females. Fish of both sexes were often seen on the stone heaps made by *Nocomis.* Because of their protective markings and slow motions, they attracted little attention from the male common shiner, and only a few times was he seen to make attempts—and these were feeble ones—to drive the darters away. These little fish were poking about the stones, evidently for eggs, but once an act was seen that was clearly that of spawning. A male sidled up to a female, and the two fish applied their bodies closely and undulated them vigorously. The breeding of this species has not been described in ichthyological literature; from the observation just described, it appears that the black-sided darter, like the rainbow darter, deposits its eggs in loose gravel and not on the lower sides of stones, as do the Johnny darter and the fan-tail darter.

Five species of fish were found laying their eggs in the gravel piled up by the two species of *Nocomis*, and it is very probable that other small fishes also use these heaps. Both the stone-roller minnow and the rainbow darter would find in them favorable places for their eggs. They were seen frequently over the piles, evidently searching for fish eggs for food; no spawning was seen. It is probable that the stone-rollers are through breeding at the time the two species of *Nocomis* begin their structures.

Besides the fishes found breeding over the accumulations of stones made by *Nocomis*, there were others in the same part of the stream breeding under other conditions. A few observations were made upon them.

Hammerhead suckers were evidently spawning on the gravel shallows at the lower end of the pool shown in Plate XXXIII, Figure 1. Here six fish were seen crowded close together. This was undoubtedly a spawning group, since Reighard (1920, p. 22) has described just such spawning aggregations for this species. A number of redhorses (*Moxostoma erythrurum*) were attempting to spawn at the lower end of a deep pool and just above riffles on May 10 and 11. A seine haul showed these fish to be about a foot in length, and both males and females in a ripe condition were caught.

Nests of the Reighard lamprey (*Ichthyomyzon unicolor*) were found on May 10, 11, and 13, 1930. All were depressions in bottom material of gravel shallows just above riffles. Plate XXXIII, Figure 2, shows a typical habitat of the lamprey; the location of the nests is indicated by the stick. Here the water was about a foot deep, and from three to seven individuals were in the nest coiling their bodies about one another. The breeding conditions and behavior were like those of the common brook lamprey (*Entosphenus appendix*) in every way, so far as observed. Reighard and Cummings (1916, p. 9) say that "the spawning act takes place almost invariably when the animals are almost hidden among stones." From our observations it was learned that the Reighard lamprey will also nest out in the open without any concealing stones or other large objects near their nests.

In a long stretch of relatively quiet water with current only slightly perceptible and with many large stones and boulders on the bottom, nests of the blunt-nosed minnow, the Johnny darter, and the fan-tail darter were found. The breeding of all these species is similar, since each plasters its eggs on the flat lower sides of stones, and since the male remains under them and becomes very bold in defending the eggs. It was possible to find these nests by wading and turning over stones; when eggs were found, the male of the species remained in or about the depression over which the stone had lain. The finding of the eggs of the fan-tail darter is worthy of special note, for although the species is common in our larger stony-bottomed streams, it was not till 1929 that we found their nests in southern Michigan. On June 14, 1929, the writer saw one with the attending male fish in Mill Creek, near Lima Center, Washtenaw County, Michigan (Pl. XXXIV, Fig. 2). Three nests of the species were found by Dr. Hubbs and the writer on May 16 and 25. With each was a male about three inches long, which had much black pigment in the skin that made him much darker than the females. The eggs, about 2 mm. in diameter, were placed close together; 150 to 300 eggs were in each patch. The breeding Johnny darters were more common, and a number of their nests were located. The eggs were considerably smaller than those of the fan-tail. Many male blunt-nosed minnows were found watching eggs under stones. Prominent tubercles on the snout and dark body pigmentation make them very different in appearance from the smaller, light-colored females and immature males. The number of the eggs varied; there were usually several hundred of them in a patch. They were distinguishable from darter's eggs by lacking the prominent oil globule. The writer was once informed of this difference by Dr. Jacob Reighard. When one of the males was taken from its nest in the Saline River, many fishes of the species, apparently mature females, rushed to the unprotected eggs and fed upon them vigorously.

All the observations previously recorded in this paper were made in the spring of 1930, but it is possible to append a few notes taken during the spring of 1931 on five visits to the same part of the Saline River near Saline, where the studies were made in 1930. The table on page 422 shows the times and temperatures of air and water during these 1931 visits.

The spring of 1931 was much later than that of the year before. On May 17, the time of the last observations, *Nocomis* were just beginning to build their stony nests; none was found completed. On two of their incompleted structures there was an association of common shiners, rosy-faced minnows, red-bellied dace and other small fishes. On account of the dim light of approaching dusk the species could not be distinguished, but the make-up was probably typical of the spawning aggregations noted in 1930. A single adorned male was in command of each group.

Many of the gravel ridges with nests built by male creek chubs in depressions at their downstream ends were found in shallows

TABLE III

CONDITIONS OF STREAM AT TIMES OF VISITS IN 1931

Time		Thermometer readings in degrees Centigrade	
Date	Hours	Air	Water
April			
4	11:00 A.M.–2:00 P.M.	16	9
18	11:00 A.M.–12:30 P.M.	20	17
May			
2	10:00 A.M.–11:00 A.M.	15	13
13	9:00 A.M.–11:00 A.M.	15	15
17	7:00 A.M.–7:20 P.M.	12	19

of pools and at the lower ends of riffles and always above them. They were typical in structure and location of the many nests of the creek chub observed elsewhere by the writer and by Reighard (1910). The ridges were from about two to three feet long. They were first noted on April 18, and many eggs of the species were mixed in with the stones in each of several nests disturbed.

Common suckers must have spawned early, for we collected two large ripe males from a pool on April 4. Clusters of hammerhead suckers, each composed of a large fish with several smaller ones crowded about it, were seen on April 18 and May 13, 1931. To judge from the descriptions of the breeding of this species by Reighard (1920), there can be little doubt but that these were spawning groups, composed of a female with smaller males crowded about her.

An unusually early record of the nesting of the Johnny darter was obtained. On the stony shallows (Pl. XXXIV, Fig. 1), where a number of nests of this species was found in May, 1930, one was noted on April 18, 1931. An adult male, with the usual abundance of black pigment was beneath the stone, on the lower flat side of which a layer of eggs was placed. There accompanied this male a female with distended abdomen. Evidently she had not spawned, but probably would have done so, contributing her eggs to those already on the lower side of the stone. It thus appears that the Johnny darter is a polygamous species, and that the eggs on the lower side of a stone are laid by more than one female.

CONCLUSIONS

In the springs of 1930 and 1931 data were obtained on the the breeding of thirteen species of fish in a portion of the Saline River, near Saline, Michigan. A list of the fish is here given:

Reighard lamprey, *Ichthyomyzon unicolor* (De Kay)
Common sucker, *Catostomus commersonnii* (Lacépède)
Hammerhead sucker, *Hypentelium nigricans* (Le Sueur)
Common redhorse, *Moxostoma erythrurum* Rafinesque
Hornyhead, *Nocomis biguttatus* (Kirtland)
Crested chub, *Nocomis micropogon* (Cope)
Creek chub, *Semotilus atromaculatus* (Mitchill)
Rosy-faced shiner, *Notropis rubellus* (Agassiz)
Common shiner, *Notropis cornutus chrysocephalus* (Rafinesque) and *N. c. frontalis* (Agassiz)
Red-bellied dace, *Chrosomus erythrogaster* Rafinesque
Black-sided darter, *Hadropterus maculatus* (Girard)
Johnny darter, *Boleosoma nigrum nigrum* (Rafinesque)
Fan-tail darter, *Catonotus flabellaris flabellaris* (Rafinesque)

The stone heaps that are built by male minnows of the genus *Nocomis* in the Saline River, near Saline, were found to be of use as breeding places of common shiners, red-bellied dace and rosy-faced minnows; in fact, these species were not found spawning elsewhere in this part of the stream, although there were many other clean gravel areas, including the ridges built by creek chubs.

The temperature of the water appears to be an important factor in determining the spawning time of common shiners and the fishes breeding in association with them and also the time of nest-building by *Nocomis*. For the initiation of all these activities, it appears that the water must be warmed to about 18° C.

Different species in the stream spawn at different temperatures. Common suckers gave evidence of spawning in water as cool as 9° C., and creek chubs in water at less than 17° C.

The two subspecies of common shiner (*Notropis cornutus frontalis* and *N. c. chrysocephalus*) appear to have identical spawning habitats and behavior, since both had holdings on the same piece of shallows and adjacent to each other.

The eggs laid by the minnows among the stones carried by *Nocomis* were eagerly sought by many small fish of the stream, which gathered in large numbers and nosed among the stones while eggs were being laid by other fishes. The species commonly noted feeding in this way were stone-rollers, blunt-nosed minnows, red-bellied dace, young hammerhead suckers, rainbow darters and black-sided darters.

The Reighard lamprey was found spawning under conditions not hitherto recorded. It made cup-shaped depressions in beds of fine gravel just above riffles and not in the vicinity of large stones. The habitat and behavior of the breeding fish were like those of the brook lamprey of other streams in southern Michigan.

The unusual opportunity to observe spawning fishes in the Saline River near Saline is correlated with the scarcity of predators, absence of pasturing animals, and freedom from molestation by people at the spawning time of the fishes.

ACKNOWLEDGMENTS

Appreciation is here expressed to Dr. Carl Hubbs for suggestions and some field identifications necessary to the preparation of this paper and for permission to use the facilities of the Division of Fishes of the Museum of Zoölogy, University of Michigan, for the purpose of studying collections made from the breeding grounds of the fish in the Saline River.

MICHIGAN STATE NORMAL COLLEGE
YPSILANTI, MICHIGAN

PLATE XXXIII

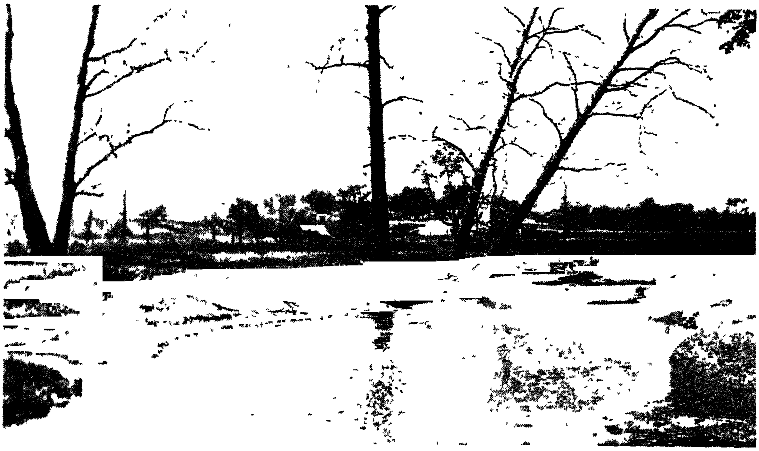

FIG. 1. Saline River, Saline, Michigan. Typical pool, about four feet deep, near overhanging tree

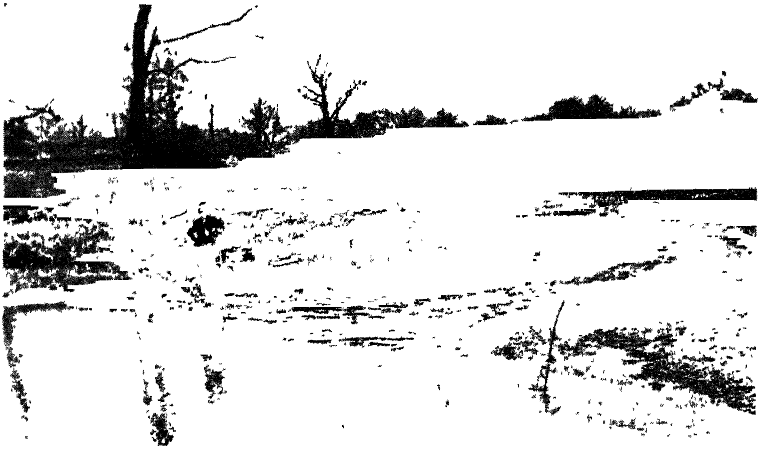

FIG. 2. Riffles at the lower end of a large pool. Above riffles an important spawning region for fish depositing eggs in gravel

PLATE XXXIV

FIG. 1. A long, deep pool or channel, about thirty-five feet wide, in the Saline River. Bottom with many stones used by fish that place eggs on their lower sides

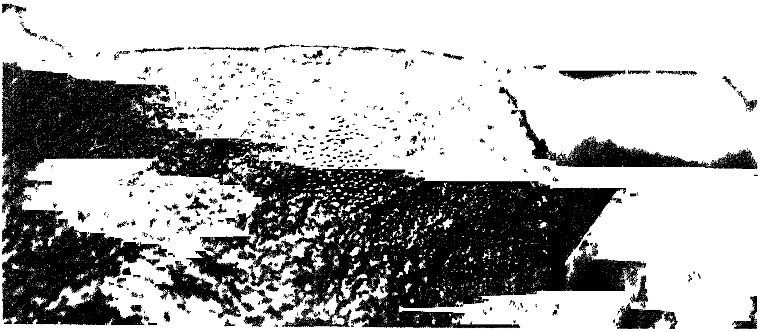

FIG. 2. Eggs of the fan-tail darter, similar to those found in the Saline River in May, 1930. Mill Creek, June 14, 1929

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EXPERIMENTAL VERIFICATION OF NATURAL HYBRIDIZATION BETWEEN DISTINCT GENERA OF SUNFISHES *

CARL L. HUBBS AND LAURA C. HUBBS

IN AN article in *Aquatic Life* (Hubbs, 1920) we discussed the apparent hybridization of sunfish species in nature, referred to similar interpretations presented by others, and expressed our opinion that the supposedly distinct but rare nominal "species" *Lepomis euryorus* is only the hybrid combination between *L. cyanellus*, the green sunfish, and *L. gibbosus*, the pumpkinseed. In our check-list of Great Lakes fishes (Hubbs, 1926, pp. 71–72) we listed other apparent hybrid combinations of sunfishes taken in nature; reiterated our opinion that *euryorus* is only a hybrid; adopted the usual view that the species *cyanellus* and *gibbosus* should be referred to distinct genera, *Apomotis* and *Eupomotis;* and presented evidence on the trenchant structural distinctness of the two genera.

Apomotis cyanellus × *Eupomotis gibbosus*

Since 1926 we have taken in nature, in various parts of the Lower Peninsula of Michigan and elsewhere, a considerable number of apparent hybrids between *Apomotis cyanellus* and *Eupomotis gibbosus.* They are always uniformly intermediate between the supposed parent species. A further analysis of their characters will be given on a future occasion, along with a discussion of their distribution and ecology. To anticipate, we may explain that these sunfish which we interpret as hybrids between *Apomotis cyanellus* and *Eupomotis gibbosus* occur most commonly, sometimes abundantly, in ponds and small lakes, the shoals of which are mostly mucky and densely overgrown with Chara. Such waters provide an abundance of food and apparently favorable conditions for growth and development. In these waters any hybrids produced might be expected to have an unusually good chance to become adult. But in such ponds and lakes there is usually only a small portion of the shoal which is fit for nesting. We suppose that an intense competition for spawning grounds exists, which would tend to throw the species together. In many cases the pumpkinseeds are the commoner, and since the males are more pugnacious on their nests than are those of the green sunfish, it is probable that few males of the more docile species are able to maintain a holding on the limited spawning grounds. Under such circumstances the mating and hybridization of male *Eupomotis* with female *Apomotis* might be expected.

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* Contribution from the Museum of Zoölogy and from the Institute for Fisheries Research, University of Michigan.

The hybridization of many fishes, of the Cyprinidae in particular, we have much circumstantial reason to believe is due to the chance meeting of egg and sperm of distinct species, but no such fortuitous hybridization is to be postulated for the Centrarchidae. All the sunfishes have a complex mating behavior, involving a nuptial gyration over the redd ("nest") prepared by the male. They breed in quiet water, in which there would be little drifting of the eggs and sperm, and they breed at some distance from one another, because the males drive other fish away from the vicinity of the nests.

To demonstrate the possibility of natural hybridization between distinct species of sunfish, we must prove not only that there exists no genetic barrier, but also that there is no psychological block. That these inhibiting barriers are not effective, we have been able to determine in the experiments here reported.

The two small adult sunfish used in the first experiment were a female of *Apomotis* and a male of *Eupomotis*. They had both been seined in Third Sister Lake, near Ann Arbor, Michigan, where we have occasionally taken the supposed hybrid between them called "*euryorus*." They were kept in a rather large aquarium, as part of an overwinter feeding experiment. They were heavily fed, and maintained in good health, at a temperature varying between 70° and 74° F. Between October 18 of 1928 and the time of spawning the female *Apomotis* grew in standard length from 80 to 95 mm.; the male *Eupomotis,* from 75 to 89 mm.

Even in the fall it appeared that the *Eupomotis* was a male, apparently of the small race (or ecological type) which is found in small lakes and streams in Michigan, especially those of a boggy nature. He was dark, had well-pigmented pelvic fins and a long red-bordered ear-flap, and showed an accentuation of the male color markings. Before the end of January a close approach to maturity was indicated by the fact that the pelvic fins had darkened nearly to black, that the margins of the caudal fin had become strongly iridescent blue-green, and that he was maintaining a clear-cut holding in one corner, from which intruders, even larger basses, were driven.

At the same time the *Apomotis* was also prematurely ripening, owing to the summer-like conditions under which it was being kept. Early in January it became evident from its distending abdomen that this fish was a maturing female. Before the end of the month she became logy, sulking among large stones in the aquarium.

When we realized that these two sunfish were now mature, the thought occurred to us that they might possibly breed together, although neither had shown any signs of sexual reaction toward the other. They were isolated on the morning of February 7 in an aquarium of similar size, like the first with gravel bottom, and balanced with Anacharis. The temperature of the water during the spawning period varied from 73° to 74° F.

Within a day the male had established its holding in one corner of the aquarium, and had partially cleaned out a nest of about 8 by 16 inches, limited in the narrower dimension by a large stone and the aquarium wall, and surrounded by an even rim of the finer gravel which had been swept aside. During the afternoon of February 8 he alternated periods of nest cleaning with attempts to excite the female by gentle nips on the abdomen and caudal fin. Once when she was near the nest he engaged in the typical circling movement, then swung out alongside of her as though to tempt her to accompany him on his gyration. But she remained aloof, generally in a far corner of the aquarium, panting as though in high distress from her swollen abdomen, even showing loss of equilibrium.

Two days after their isolation, on February 9, the pair was much more active. Usually the female paid no attention to her forced partner, except to escape from his lunges. However, before noon they had sprinkled the nest with eggs, and during the afternoon actual spawning was observed, accompanying the typical nuptial gyration.

Within 24 hours after fertilization an egg picked at random showed a well-formed embryo encircling about two thirds of the egg. On this day the male maintained the typically faithful guard over the nest, even biting at one's fingers when placed against the glass near by. Before the actual spawning he twice attacked two large angleworms which had crawled into the nest, driving one off and carrying the other to the opposite end of the aquarium.

After the spawning the female was removed. On the morning of the next day she was replaced with her mate, but neither showed any reaction to the other. She was obviously now spent, and since pressure caused only a few eggs to be extruded, she was soon returned to the feeding experiment. On the next day she showed painful signs of her nuptial treatment: her caudal fin was nearly gone, the posterior half of her body was scaleless and inflamed, and an eruption had arisen behind the head. She died the next day.

The rough treatment and resulting death of this female should probably be accredited to her weakness rather than to miscegenation. Another male pumpkinseed and female green sunfish spawned together freely, in a similar aquarium, on May 29, 1930, without any nipping of the female or injury to her. She spawned out her roe with the male, very soon after he had prepared his nest, on the second day of their segregation. Neither showed any signs of hesitation or repugnance at the mating. The eggs appeared normal, but were killed by fungus before hatching.

On February 15 about two hundred baby fish of the pioneer aquarium brood were discovered in the spawning tank from which the male had been removed two days before. Most of the babies were cultured in the large spawning tank, but several were removed to smaller ones. They were fed first on small protozoans, then on *Paramoecium,* then on chopped tubificid worms. By late March the larger individuals took whole tubificid worms and mosquito larvae. During the summer the fast-growing young were fed on chopped angleworms, tubificids, dried shrimp, fly larvae and finely shredded bird meat. Over the fall and winter they were fed an increasing proportion of bird meat, which we have found very satisfactory for sunfish.

As is usually true with aquarium-raised fish, there was a heavy initial mortality. During the first month all but about forty-six had disappeared. After that time, however, few died, in fact only five during the whole year, to March 15, 1930.

The growth of the young sunfish, after their initial adjustment, was rapid. At just one year of age they ranged in standard length (exclusive of caudal fin) from 35 to 95 mm., with an average of 54 mm. Their first year's growth exceeded by 18 mm. that of thirteen natural hybrids of the same combination, which had spent their first growing season in a large pond and were measured in February. The increased growth was probably due to the fact that they were hatched much earlier and continued to grow over the winter. The first year's growth of the experimental hybrids exceeded by even a larger amount the first season's growth of either parent species, in the same pond in which the natural hybrids had grown. A comparison between the growth of these hybrids and of their parent species is given in a recent paper (Hubbs and Hubbs, 1931), in which a markedly increased growth is demonstrated.

These experimentally produced hybrids are intermediate between the parent species in every obvious respect except growth-rate, and correspond finely with the natural hybrids which we now can feel assured are the products of the natural mating of *Apomotis cyanellus* and *Eupomotis gibbosus.* They are less rough than *Eupomotis,* but less slimy than *Apomotis,* a difference easily felt. They are slenderer yet thicker than *Eupomotis,* but not so slender nor so thick as *Apomotis.* Their gill-rakers are of intermediate length. Their pharyngeal arches and teeth are intermediate with the exception that the teeth are as sharp as usual in *Apomotis;* this sharpness of the teeth is no doubt the consequence of the softness of the food used. Their cheeks are deeper than in *Eupomotis* and their mouths larger, but they are not so extreme in these characters as *Apomotis.* Their fins are lower (or shorter) and rounder than in *Eupomotis,* but not so low and round as in *Apomotis;* this is especially true of the pectorals and the anal spines. The pelvic and anal fins show a trace of the pale borders of *Apomotis.* The opercular spot has a coppery red border, more diffuse than the brighter red spot of *Eupomotis.* The general body color involves some of the olive-rust undertone and the violet luster of *Apomotis.* The scattered coppery flecks of *Eupomotis* are represented, but rather dully. The banding is more conspicuous than in *Apomotis,* but less so than in *Eupomotis.* The bluish interspaces between the bars are each marked rather regularly by a row of dark spots, almost as are those of *Apomotis.* The general color effect is more checkered than that of either parent species, but this effect seems to result from a combination of the color characters of the two.

The general appearance of these hybrids is charming. They make very desirable aquarium fish, for they are active as well as beautiful.

The reciprocal cross

In 1931 we were so fortunate as to obtain the reciprocal cross, *Apomotis* male × *Eupomotis* female. The male, 146 mm. long to caudal at the time of spawning, originally taken in Fox Lake, northern Illinois, was furnished to us by Mr. Walter H. Chute, director of the Shedd Aquarium in Chicago. The female, 138 mm. long, was caught in Frains Lake near Ann Arbor. The male had been nurtured in our aquaria under summer conditions since January 16, and the female since March 21. On June 13 they were isolated in a large aquarium; four days later the male had constructed his redd, and on the morning of June 22 the nest was covered with eggs. Of a dozen eggs examined that afternoon, only one was found dead. On the morning of the next day the eggs were hatching. After a few days the tank was filled with many hundreds of active, normal fry. Most of these died as a result of a mishap, but fifteen lived on, and of these eleven survived and grew into replicas of the offspring of the reciprocal cross and of the natural hybrids of the same combination.

Eupomotis gibbosus × *Helioperca incisor*

During the spring of 1930 experimental studies were made on the hybridization of other sunfish combinations. A maturing pair, made up of a male of *Eupomotis gibbosus* and a female of *Helioperca incisor*, was isolated on April 25, in hope of obtaining confirmation of our identification of a considerable number of natural hybrids as of this combination. After June 30 a second maturing male of *Eupomotis* was kept in the same tank. These fish had apparently not become fully mature; at least no spawning had taken place before they were accidently killed on June 8. Some days before her death the female was observed to approach the males wildly and to rub against them — possibly a reversal of sex behavior.

Numerous attempts to hybridize *Eupomotis* and *Helioperca*, by both of the reciprocal crosses, were unsuccessfully made in the spring of 1931, both in aquaria and in larger wire pens in Third Sister Lake near Ann Arbor. In each container the failure to get results was apparently due to the fact that the females were all killed, or died off.

Apomotis cyanellus × *Xenotis megalotis megalotis*

An effort to check experimentally our interpretation of some aberrant specimens of sunfish as of an *Apomotis* × *Xenotis* combination resulted in only slightly more success. The green sunfish female which had not shed all her eggs in the mating with the dwarf bluegill, as recounted below, was mated on June 4, 1930, with a ripe, adult, male long-eared sunfish, which had been captured a few days previously in Tippecanoe River, Indiana. On June 12 the resulting eggs were found badly fungused. Just one month later the female had matured a new batch of eggs, and again spawned with the male *Xenotis*. Segmentation was observed before these eggs also were lost by fungus.

Eupomotis gibbosus × *Xenotis megalotis megalotis*

An attempt to mate a ripe female long-eared sunfish with a pumpkinseed male resulted in the killing of the female by the pugnacious male, who proceeded to bite the female furiously after he had built his redd. We therefore still have only circumstantial evidence on this hybrid combination, which appears to be of infrequent natural occurrence.

Varied attempted matings of both males and females of *Xenotis megalotis peltastes* with other genera of sunfishes, conducted in 1931, met with no success whatever, although these fish were fully mature when brought into the aquaria. They showed no effort to mate either among themselves or with other species.

Apomotis cyanellus × *Helioperca incisor*

On March 31 a male bluegill and a much smaller female green sunfish, both approaching maturity, were isolated in one of the large aquaria. The length to caudal of the bluegill, which had been in the aquarium for a year and a half, was 124 mm. just after spawning. The length of the green sunfish, which was brought into the aquarium when not yet a year of age, was measured on several occasions, from February, 1929, to April, 1930: February 9, 36 mm.; May 12, 46 mm.; October 5, 56 mm.; December 13, 61 mm.; February 10, 68 mm.; April 30, 77 mm. Both these fish had therefore been maintained for many months in captivity, and had been in good health. After their isolation the pair occupied opposite ends of the tank, the bluegill in a corner beside a large stone, and the female in vegetation.

These fish showed no sexual reaction toward each other until the late morning of April 29. The male was then completing the construction of a very small nest, not more than 15 cm. in diameter, in the corner behind the large stone. This he was doing with the usual tail-sweeping. A few minutes later, the female, which had become very full of eggs and somewhat unbalanced, swam without any forcing or prompting over to the scene of miscegenation, circled the nest with the male, then momentarily retired but again returned within a few minutes for a renewal of the spawning behavior. After that she resisted the attempts of the male to entice her again into the nest, and the next day he drove her away from near his retreat. An examination showed a large number of apparently normal eggs sprinkled over the gravel surrounding the little clearing. High hopes were held for a new batch of hybrids, this time of a combination rather rarely taken in nature, except in the Southwest, where it is common. Unfortunately, however, just about the time the eggs were expected to hatch, on April 2, the male was abandoning the nest, a huge crop of *Cyclops* appeared, and no eggs or larval fish could be found. Whether it was the male fish or the crustaceans which ruined the experiment cannot be said. But the experiment apparently demonstrated that no physiological barrier prevented the inception of this hybrid development, and certainly showed for this combination, more clearly than had been indicated by the pumpkinseed-green cross, that no unbreakable psychological barrier exists to prevent the mating of *Helioperca* with *Apomotis*. From this mating the female survived without any apparent ill effects.

The same male of *Helioperca*, being still ripe, was later (May 5) isolated with another female of *Apomotis*, which since its capture on February 23 had matured in an aquarium to a much-swollen condition, accompanied by slight loss of equilibrium. The male at once showed a decided reaction toward the female, making wild dashes toward her but not actually biting. The female reacted by swimming away only a slight distance, and occasionally even approached the male voluntarily. Later she lurked in the weeds. On May 23 the male swept out a small redd, and on the following day greatly enlarged it.

The pair thereupon spawned in normal fashion. They gyrated over the redd. The male kept on the outer side of the circle and remained upright. Occasionally he swam over the female as though to push her over, and at times nipped her posterior region. She often turned over beyond a horizontal position, with anal region next to that of the male. The male showed great excitation when the female tried to desert the nest, until it was well sprinkled with eggs. After a period of rest spawning was resumed.

The eggs hatched in three days, and the young developed rapidly. Some of the larger ones were approaching maturity when less than a year old. The offspring of this *Apomotis* × *Helioperca* mating are, like those of the *Apomotis* × *Eupomotis* cross, uniformly intermediate in form, structure, color pattern and coloration between the parent species. The experimental hybrids furthermore agree finely in all ways with examples taken in nature, occasionally in Michigan, commonly in the Southwest. On this hybrid type apparently was based the name *Lepiopomus ischyrus* Jordan and Nelson.

The laboratory crossing of *Apomotis* and *Helioperca* was almost simultaneously repeated and verified. On June 8 a large hatch resulted from the mating of an exceptionally dwarfed bluegill with a small green female sunfish. Many of these have remained alive, and agree with those of the other mating.

The *Apomotis* × *Eupomotis* hybrids also showed a very rapid growth rate. The 31 remaining offspring of the first mating when one year old varied from 46 to 96 mm. long to caudal (average, 64.6 mm.), and the 30 offspring of the second mating at the age of one year varied from 48 to 119 mm. (average, 69.5 mm.).

SUMMARY

Experimental verification has been obtained of the hybridization in nature of sunfishes which are referred to distinct genera. In several matings of different combinations in aquaria the normal nuptial behavior of the sexes was observed, proving that no complete psychological barrier blocks the mating of these sunfishes. Four matings have each resulted in the production of numerous offspring, which shows that no genetic barrier prevents the intergeneric hybridization. The experimentally produced hybrids are completely like the supposed hybrids taken in nature, uniformly and exactly intermediate in all respects between the parent species.

CONFIRMATORY EVIDENCE

The hybrid nature of the naturally produced specimens is confirmed by the observations that they, as well as the known hybrids experimentally produced, are with rare exceptions all males and that they have in our experience all proved to be infertile.

This paper will be followed by others dealing with the sex ratio and with the infertility of the sunfish hybrids.

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TAXONOMY AND DISTRIBUTION OF THE FRESH-WATER SPONGES (SPONGILLIDAE) OF MICHIGAN *

MARCUS C. OLD

SPONGILLIDAE are widespread over the earth, yet the literature dealing with them contains little more than fragmentary data, some of which are completely in error. Such errors, which have been copied over and over again, are greatly in need of correction. This paper is an attempt to add to the meager knowledge of the taxonomy and distribution of *Spongillidae* in the United States. It is anticipated that similar work will be done for other states in the near future. During the summer of 1929 the writer made a rather thorough ecological survey of sponge habitats that are scattered throughout the state of Michigan, and collections were made from eighty-four streams, forty-two lakes and nineteen ponds. These collections, together with earlier ones, comprise the basis of this report.

MATERIALS AND METHODS

A collapsible pneumatic rubber boat was used throughout the season to facilitate examination of parts of water units otherwise inaccessible. After collection and description, sponges were placed in low card boxes with absorbent paper bottoms and were exposed to the sun and air at every opportunity. Most specimens could be dried quite thoroughly in this fashion in from six to eight hours, but occasionally, if there was wet weather, or if the sponge was quite large, artificial heat had to be applied. After becoming quite dry, each specimen, together with its number and record was wrapped in two sheets of paper napkin and stored in small wooden boxes.

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* Contribution from the Biological Station and the Zoölogical Laboratory of the University of Michigan.

Upon the writer's return to the University in October, 1929, these sponges were filed in covered cylindrical cartons, which were marked on the outside in ink, to correspond with the number of the sponge on the inside, and arranged in series on shelves which afforded easy access for later examination. The condition of each sponge after shipment to the laboratory was excellent, differing from its original condition only in that it was drier, more fragile and paler.

Dried specimens of fresh-water sponges are more favorable for taxonomic purposes than specimens preserved in fluid. Fragments of dried sponge can be boiled easily and quickly in concentrated HNO_3, without any accompanying formation of foam and explosions, such as result when the material has been soaked with formaldehyde or alcohol.

The methods of Annandale (1911), Arndt (1928*a*), Crawshay (1915), Lendenfeld (1904), Potts (1887), Weltner (1909) and others have been tried, but a modified technic, as given below, has facilitated the work on which this paper is based.

SLIDE PREPARATIONS OF SPICULES

Representative portions of the sponge and its gemmules were placed in a test tube, 50 × 10 mm., containing about 0.25 c. c. of concentrated HNO_3, and boiled over a low flame until the sponge mass had completely disintegrated. After cooling, the tube was filled with clean water, shaken thoroughly, and set aside to allow the spicules to settle. The fluid was then siphoned off with a suction pump, after which the tube was refilled with clean water and again shaken thoroughly. In this manner the spicules were washed a second time. After the fluid was withdrawn for the third time, it was replaced with 96 per cent alcohol — the amount needed depending on the quantity of spicule deposition in the tube — and shaken thoroughly. A portion of this alcoholic, temporary suspension of spicules was then immediately poured on a cover-slip, 7/8-inch circle No. 2, and ignited. Burning the alcohol assured a quick and neat preparation, leaving the spicules clean and well distributed over the slip. A drop or two of the Damar mounting medium was then added and the slip inverted on a glass slide.

SLIDE PREPARATIONS OF GEMMULES

Gemmules of a selected specimen were placed in a test tube, 50 × 10 mm., containing 0.25 c.c. of cold concentrated HNO_3, and allowed to stand until the gemmules lost their opaqueness and became more or less cleared. Workers heretofore have always used hot HNO_3, but in the author's opinion cold HNO_3 is just as satisfactory and is less annoying. The gemmules were then washed several times in clean water and dehydrated by additions of 35, 50, 70, 82, and finally 96 per cent alcohol at about 15-to-30-minute intervals, and then cleared in carbol-xylol. The gemmules were removed with a camel's-hair brush and placed on a glass slide, to which the Damar mounting medium and a cover-slip were then added.

IDENTIFICATION OF SPECIES

Key to the fresh-water sponges of Michigan

In the construction of this key only the most essential systematic characters are used. Other distinguishing characters can be discovered by consulting the technical descriptions of the various species.

1	(8)	Gemmule spicules either acerose or subcylindrical	2
2	(7)	Skeleton spicules smooth amphioxi	3
3	(6)	Flesh spicules present; amphioxous	4
4	(5)	Flesh spicules spined	*Spongilla lacustris*
5	(4)	Flesh spicules smooth	*Spongilla aspinosa*
6	(3)	Flesh spicules absent	*Spongilla fragilis*
7	(2)	Skeleton spicules spined	*Spongilla igloviformis*
8	(1)	Gemmule spicules birotulate; more or less modified	9
9	(16)	Birotulates of one class	10
10	(15)	Rotules equal	11
11	(14)	Shaft of birotulates longer than rotule diameter	12
12	(13)	Rotules with 3–6 short recurved rays; shaft very much longer than rotule diameter	*Ephydatia crateriformis*
13	(12)	Rotule discs not deeply serrate; shaft little longer than rotule diameter	*Ephydatia fluviatilis*

14 (11) Shaft of birotulates of same length or shorter than rotule diameter; discs deeply serrate .... *Ephydatia mülleri*
15 (10) Rotules unequal .... *Trochospongilla pennsylvanica*
16 (9) Birotulates of two classes 17
17 (22) Tubular foramen of gemmule, if present, not possessing filamentous appendages 18
18 (19) Flesh spicules present; spined amphioxi .... *Heteromeyenia repens*
19 (18) Flesh spicules absent 20
20 (21) Rotules of smaller class finely serrate .... *Heteromeyenia ryderi*
21 (20) Rotules of smaller class coarsely serrate *Heteromeyenia argyrosperma*
22 (17) Tubular foramen of gemmule possessing filamentous appendages .... *Carterius tubisperma*

TAXONOMIC REVISIONS

Tubella pennsylvanica Potts is here designated *Trochospongilla pennsylvanica* (Potts), after the suggestion of Annandale (1911). The genus *Trochospongilla* is characterized by its smooth-margined birotulates. The smooth discs of the birotulates are not always of the same size; some birotulates show distinct differences in size. "Tubella" is reserved by Annandale to designate the forms in which the unequal birotulate discs differ not only in size but also in form. The small disc is a rounded knob; the larger is serrated and flat.

Annandale (1908) also suggested placing *Carterius tubisperma* Mills in the genus *Heteromeyenia.* Schröder (1927*a*), revising the genera *Carterius, Astromeyenia* and *Heteromeyenia,* classifies *Carterius tubisperma* Mills as *Heteromeyenia tubisperma* (Mills), and *Heteromeyenia repens* Potts as *Heteromeyenia baileyi* (Bwk.) var. *repens* (Potts). The author, however, is of the opinion that the remarkable appendaged tubular foramen is sufficiently distinctive to warrant the retention of the original genus created by Mills. Likewise, *H. repens* Potts appears sufficiently distinctive from *H. baileyi* (Bwk.) to stand alone.

EXTERNAL FEATURES

Fresh-water sponges cannot be identified positively by external features alone, since variations and similarities of appearance and surface morphology are too common. Frequently, a sponge may be recognized in the field by an examination of its gemmules, as is the case with *S. fragilis*, *S. igloviformis* and *C. tubisperma*. Branched colonies are not always *S. lacustris*, and colonies of *S. lacustris* are not always branched. One is apt to conclude from the literature available that only *S. lacustris* may be a branched colony and that unbranched colonies of this species are abnormal. Branched colonies are also found in *S. aspinosa* and *H. repens*. Short, blunt, finger-like projections are found in *E. mülleri*, *H. ryderi*, *H. argyrosperma* and *C. tubisperma*.

The writer found unbranched and branched colonies of *S. lacustris* side by side in lakes and streams. The reason for this is not known. According to Carpenter (1928), the branched form occurs in lakes and the flat type in streams; the flat type is a response to an adverse condition caused by the rapidly flowing water. Her example is designated as "*Spongilla* (*Ephydatia*) *fluviatilis*," with illustrations of a lake form corresponding to *S. lacustris* and a running-water form corresponding to *E. fluviatilis*. Carpenter, apparently, confused two different species. Unbranched colonies were held by Annandale (1911) to be the result of unfavorable conditions. This can hardly be true when both forms are found side by side in the same water on similar supports.

ODOR

Van Trigt (1919) claimed the ability to distinguish *S. lacustris* from *E. fluviatilis* by its pungent smell, i.e. "pungent for instance as formol." This method, however, must remain a doubtful one. Fresh-water sponges have a peculiar characteristic odor, variously described as bad or similar to that of garlic. The latter description appears the better one to the writer; it served as a good field test for some of the fleshy sponges which otherwise have little resemblance to sponges, so far as a porous nature is concerned. Although the author has made use of this test in field recognition of sponges, he has not found it possible to distinguish by odor different genera or species of sponges. It is doubtful whether this characteristic odor of fresh-water sponges can be satisfactorily described on paper, for, apparently, recognition of it can come only through personal experience with the material.

GEMMULE PRODUCTION

According to Potts (1918), gemmules may be found on the rarer, filmy sponges as early as August, though on the more lusty, massive forms the gemmules may still be lacking late in November. Annandale (1911) states that in Europe, North America and Japan gemmules are produced at the approach of winter. The experience of the writer during the season of 1929 shows, however, that one may expect to find sponges with gemmules early in any favorable season. In fact, *S. fragilis* and *E. mülleri*, in a pond, were both found with new gemmules on June 27. By July 8, additional specimens bearing new gemmules included *S. fragilis*, *E. mülleri*, *E. fluviatilis*, *T. pennsylvanica*, *H. repens*, *H. ryderi* and *C. tubisperma*. The only species which appeared to delay gemmule formation until late in the season (September or October) was *S. lacustris*, which was repeatedly taken in streams and lakes, but only occasionally bore gemmules in early summer. Of the total number of sponges collected (539), only 82 (15 per cent) could not be identified through lack of gemmules. Thus it is seen that sponges do not necessarily wait for the approach of winter to produce gemmules, although it should be stated that the probability of finding gemmules in large quantities is greater then than at the start of the favorable season. The production of gemmules at various times during the summer has been repeatedly observed in other years by the writer and his associates.

DESCRIPTIONS OF SPECIES

The general part of the descriptions, unless otherwise noted, consists of summaries of data accumulated by the author from *living* material. At the time of collection, data on the following characteristics were made for each sponge: habitat, shape and dimensions, surface, color, pores, texture, external membrane, basal membrane, and location, color and abundance of gemmules.

The part dealing with the spicules and foramen of gemmules is a composite description built from all the slide material for the species.

The descriptions are unique in that they represent a summary of many individual descriptions made from sponges scattered over the state of Michigan. The descriptions are, therefore, comprehensive instead of narrow in their application.

Spongilla aspinosa Potts

Jewell and Brown (1929) found this sponge growing abundantly in an acid lake (Malony Lake, Cheboygan Co., Michigan; pH 5.0), attached to fragments of wood and the soft false bottom, but give no technical description of it. The following characters are taken from Potts (1887):

Skeleton spicules smooth amphioxi; straight or slightly curved; rather abruptly pointed.

Flesh spicules minute amphioxi; straight or curved; smooth; slender.

Gemmule spicules resemble the skeleton spicules.

This species did not occur in any of the writer's collections. Apparently, it is rare in Michigan.

Annandale (1916) reports a specimen from Lake Biwa, Japan, under the name *S. aspinosa*, which differs from the type in that it possesses spined flesh spicules. The gemmules are surrounded by an irregular but dense network or cage of skeleton spicules.

Spongilla lacustris Auctorum

Sponge found in quiet or rapidly flowing water, attached usually to upper side of stones, timber and vegetation. Body usually soft and loose with a well-marked external membrane; colonies of two types, branched and unbranched. Color green in sunlight; a gray, yellow or orange in constant shade. Filaments of branching type sometimes attaining length of 10–11 inches, and a width of 1/4–5/16 inch; flat spreading type sometimes 9 × 4 inches or more; spindle-shaped colonies attaining a length of 8 inches and thickness at middle about 3/4–1 inch. Gemmules yellow or orange; distributed all through sponge body; foraminal aperture infundibular.

Skeleton spicules smooth amphioxi; straight or slightly curved;

variable in length and breadth in same specimens and to greater extent in different specimens.

Flesh spicules finely spined, slender amphioxi; straight or slightly curved.

Gemmule spicules subcylindrical; ends pointed or rounded; variably curved or straight; spined.

Spongilla fragilis Leidy

(Pl. XXXV, Figs. 1–4)

Sponge found in both quiet and running water on upper or lower side of submerged stones and wood as flat spreading colonies, as large as 12 × 15 inches; or on twigs, branches and similar objects, usually forming spindle-shaped colonies as much as 16 inches long and 1 1/2 inches thick at middle; or on muddy, sandy or gravel bottoms as globular colonies. Body rather firm; surface rugged, occasionally quite smooth; oscula in well-developed specimens large and conspicuous, often somewhat raised; external membrane usually noticeable. Thickness of sponge frequently 1/8–1/4 inch; in largest specimens 1 1/2–2 inches. Color usually green, but when growing in constant shade, gray, yellow, brown or pink; muddy or stained waters, or supporting materials may impart unusual shade of brown, lavender or chocolate color. Gemmules bound together in free groups of varying numbers or in pavement layer on support; color, depending on age, varying from whitish through yellow, orange and dark brown; foraminal aperture prolonged into tubes on outside, frequently curved.

Skeleton spicules smooth amphioxi; straight or nearly so; varying in length, breadth and degree of sharpness in same specimen, but to greater extent in different specimens (Figs. 1–4 A). Spicules occasionally with globular swellings at middle, or series of globular swellings along axis. Abnormal skeleton spicules (Schulze, 1923) rarely present (Fig. 4 C); also spicules with distinct axial canals.

Flesh spicules wanting.

Gemmule spicules spined amphioxi or amphistrongyli; straight or slightly curved; length, breadth, termination and quality of spination may vary in same specimen. Certain specimens with spined subcylindrical spicules (Fig. 1 B); others with spined acerates (Fig. 2 B); still others with mixture (Figs. 3–4 B). Abnormal gemmule spicules (Schulze, 1923) with distinct axial canals and subcanals extending into spines also present (Fig. 1 C). Abnormal spicules in form of pycnasters or sphaerasters (Fig. 3 C) present in some specimens.

Spongilla igloviformis Potts

Sponge abundant in sheltered cove of lake on the bottoms and sides of submerged 10–12-inch logs. Body thin, incrusting, fleshy; surface smooth, except projecting points of skeleton spicules. Average size 7 × 3 inches. Color variable: light grayish, light brown, dark brown or green. Gemmules yellow to orange, in scattered hemispherical groups upon substratum. Cellular parenchyma surrounding gemmule groups; tubules turned inward.

Skeleton spicules slender spined amphioxi; not abundant; spines coarse, scattered.

Flesh spicules wanting.

Gemmule spicules like skeleton spicules, but generally shorter and more numerous.

Trochospongilla pennsylvanica (Potts)

(Pl. XXXVI, Figs. 6–7)

Sponge found in relatively quiet water usually beneath stones, timber, twigs, and the like, rarely on upper side of objects. Body thin, fragile; surface even, smooth; external membrane usually noticeable. Colonies mostly small, none exceeding 4 × 1 1/2 inches. Prevailing color gray, occasionally green or light yellow. Yellow gemmules scarce, occurring free in sponge body; foramen infundibular.

Skeleton spicules abundantly spined; ends rounded or pointed; length and breadth (Figs. 6–7 A) varying in different specimens.

Flesh spicules wanting.

Gemmule spicules unequal birotulates. Shaft smooth; with smooth-margined disc at one end and minute disclike structure at other end. Some specimens exhibit an additional kind of unequal birotulate possessing a large disc with six or more distinct rays leading from shaft almost to margin of disc (Figs. 6–7 C).

Ephydatia crateriformis (Potts)

One specimen found incrusting lower side of plank in sluggish stream; body very thin, flat and spreading; size, 7 × 5 inches. Color white, owing to abundance of white gemmules lying against substratum.

Skeleton spicules slender amphioxi; sparsely macrospined.

Flesh spicules wanting.

Gemmule spicules of birotulate type; shafts cylindrical, long, and macrospined mostly toward ends; rotules with 3–6 short, recurved rays.

Ephydatia fluviatilis (Auctorum)

Sponge found on upper and lower sides of timber, stones, branches, roots and the like, in quiet or rapidly flowing water partially shaded. Body quite hard, firm; surface usually irregular with blunt lobular projections, or very even; oscula prominent, circular; forms subcircular spreading patches varying from those one-half inch in diameter to areas of about 400 square feet, continuously distributed over bed of stones and gravel. Color dark yellow, or cream, light or dark yellow, brown and green. Gemmules abundant and free throughout body of sponge, or in basal region; foramen infundibular, inconspicuous.

Skeleton spicules smooth amphioxi; occasionally with few microspines.

Flesh spicules wanting.

Gemmule spicules birotulates; shafts longer than diameter of rotule; rotule moderately serrate. Shafts usually smooth; sometimes spined to lesser or greater degree.

Ephydatia mülleri (Lieberkühn)

(Pl. XXXVI, Fig. 5)

Sponge found attached to stones, timber, vegetation, and similar objects, in quiet as well as rapidly running water; body fragile; surface rarely even, usually rugose, or with close stout finger-like projections attaining length of 1 1/4 inches; color green, yellow, brown, or gray. Gemmules of various shades of yellow and orange; scattered throughout sponge.

On timbers or on cement abutments of bridges sponge may develop to a length of 40 inches and a width of 20 inches, with a depth of 4 inches at middle; spindle-shaped colonies coating slender branches may become 16 inches long and 5 inches wide.

Skeleton spicules smooth to abundantly spined amphioxi; straight or slightly curved; all kinds occasionally in same specimen.

Flesh spicules wanting.

Gemmule spicules birotulates; shaft of same length or shorter (usually) than diameter of rotule; rotules flat; irregularly and deeply serrate, depth of serration almost to hub of rotule. Occasionally many malformations (Fig. 5 B) (Wierzejski, 1912). Gemmule spicules in more than one layer in some specimens.

Heteromeyenia repens Potts

(Pl. XXXVII, Figs. 11–12)

Sponge found in quiet and slowly running water, coating twigs, roots, leaves, wood and vegetation. Body rather loose; surface quite smooth, rugose or elevated into short narrow projections, often subbranched on submerged finely divided vegetation; external membrane usually wanting. Most frequent on upper side of objects, growing to length of 8 inches and thickness of about 1/8 inch. Color green or whitish. Yellow gemmules free in body of sponge at or near base.

Skeleton spicules amphioxi; sparsely spined or smooth (Figs. 11–12 A); straight or slightly curved; length and breadth of spicules vary to great extent in different specimens.

Flesh spicules heavily spined amphioxi; straight or curved; spines (Figs. 11–12 D) perpendicular and longest at middle.

Gemmule spicules of two classes; small birotulates with moderately serrated rotules and smooth shafts (Figs. 11–12 B), or at most possessing few spines; larger birotulates with rotules of many distinct, recurved spines; shafts (Figs. 11–12 C) usually with one or more macrospines near middle.

Heteromeyenia ryderi Potts

(Pl. XXXVII, Figs. 9–10)

Sponge found in quiet or slowly running water, usually incrusting bottoms of stones, timber or vegetation. Body rather loose and watery, not attaining great size; surface in larger specimens interrupted by thin, very short projections; smaller specimens smooth; external membrane present or wanting; forming irregular low masses, 1/4–3 inches in greatest diameter. Color gray, yellow or green. Gemmules free in tissues of sponge at or near base; recognizable as minute white or yellow grains.

Skeleton spicules spined amphioxi; straight or slightly curved; length and amount of spination variable in different specimens (Figs. 9–10 A), depending probably on maturity of sponge.

Flesh spicules wanting.

Gemmule spicules birotulates of two classes; smaller class with well-developed rotules finely serrated and usually with smooth shaft; larger class with rotules of heavy recurved spines and shaft usually possessing one or more spines and swelling at middle (Fig. 10 C); one immature specimen exhibited gemmule spicules (Fig. 9 B–C), although no gemmules could be isolated.

Heteromeyenia argyrosperma Potts

Sponge incrusting upper and lower sides of stones, timber and vegetation in quiet or rapidly running water. Body quite loose, thin; surface often more or less even; on finely divided vegetation, short narrow filaments as much as 1 inch long and 1/8 inch wide usually present; external membrane sometimes with a slime. Maximum size, 6 × 3 inches; flat, spreading. Gemmules yellow, free in body of sponge near basal region.

Skeleton spicules amphioxi; sparsely spined; spines projecting toward extremities of spicule.

Flesh spicules wanting.

Gemmule spicules birotulates of two classes; larger class robust with long shafts, usually with long recurved spines; rays of rotules clawlike. Shorter class abundantly spined; rotules flatter with rays irregularly hooked.

Carterius tubisperma Mills

Sponge attached to submerged stones, wood, vegetation, usually, on upper side, in quiet or rapidly flowing water. Body soft and cushion-like; external membrane usually present; surface rarely even, mostly rugose or with many close-set short projections, 1/8–1/4 inch long. Largest specimen collected by writer, attached to gravel and overspreading it on creek bed, 20 inches long, 8 inches wide, 4 inches thick. Color usually green, occasionally brown or yellow. Gemmules yellow; free in basal portion of sponge.

Skeleton spicules sparsely microspined amphioxi; occasionally smooth; length and breadth mostly uniform in same specimen, but varying in different specimens.

Flesh spicules long slender amphioxi; straight or slightly curved; entirely spined; spines at middle longest.

Gemmule spicules birotulates; irregular in length, suggesting two classes; larger birotulates with rotules of distinct recurved rays; smaller ones usually with flat rotules showing distinct rays; shafts of both kinds occasionally smooth, usually more or less macrospined.

This sponge can be recognized in the field with a common hand lens. An examination of the gemmules will reveal a tubular foramen ending in 4–6 long slender tendrils.

DISCUSSION

Variation in spicules. — Sponges have been commonly described from single or few specimens from the same or different localities, with the result that consequent narrow descriptions have encouraged further designations of varieties and subspecies. The writer has purposely avoided varieties and subspecies because he believes the taxonomy of fresh-water sponges is better served without them until more data will have been accumulated.

The literature contains numerous examples of variation among sponges which have been incorporated into varieties or subspecies, and which later have been revised as "simply a very common variant form of a highly variable species" (Smith, 1921*a*).

S. fragilis, of which one hundred and sixty-eight specimens were collected, shows four variations in form and kind of spicules, not one of which is sufficiently distinctive to justify designation as a variety.

Some of the material included under *Trochospongilla pennsylvanica* in this paper may possibly belong to a new species of that genus. Thus far descriptions have contained no mention of gemmule spicules in which some smooth-margined discs are rayed (Pl. XXXVI, Figs. 6–7 C), but they are otherwise similar to those of the type specimen. This could probably be designated a variety or subspecies. The author prefers, at present, to list this form as *T. pennsylvanica.*

E. mülleri, as has been noted by others, is also a highly variable species in Michigan. This is evident not only in the quality of spination of the skeleton spicules, but also in the extreme types of gemmule amphidiscs. Rotules may be entirely missing and may possess only a few rays irregularly placed; or the rays of the rotules may present various conditions of spination. Ordinary amphidiscs and these extreme forms usually occur together.

One specimen of *H. repens* shows smooth instead of sparsely spined skeleton spicules. In this respect it agrees with *Heteromeyenia insignis* Weltner (1895). *H. insignis* is further described with numerous spines on all birotulates and with long spines of the flesh spicules terminating in a knob. Since the Michigan specimen represents but one collection and differs in some minor characters, one hesitates to designate it *H. insignis,* a species which is recorded only from Brazil. Specimens occur in which the spinose character is weak, and it is conceivable that a condition might arise in which the skeleton spicules are aspinose.

Globular swellings at the middle of spicules, or a series of globular swellings, are found in some preparations. Such swellings have been recorded by Arndt (1926), Müller (1911), Wierzejski (1912) and others for practically all the common species, in both immature and adult specimens. In the writer's collection it has been noted that such swellings occur mostly on slender skeleton spicules from small specimens growing on decaying leaves and soft stems or on rotting timber. This fact has not been mentioned by previous workers, who are unable to account for the swellings. Circumstantial evidence suggests that possibly these swellings result from pathological conditions arising from the decay of the supporting substance. Nothing definite, however, can be stated at this time.

Unusual skeleton spicules. — In the fall of 1927 the writer found peculiar modifications in skeleton spicules in two sponges from the Grand River, near Lansing, Michigan. One colony, a rock-incrusting form of *E. fluviatilis*, with an abundant growth of filamentous algae mixed in it, contained many skeleton spicules with wide axial canals, open at both ends, which occupied more than one half of the breadth of the spicule. Slides prepared by boiling spicules in both HNO_3 and KOH showed it. Similar skeleton spicules have been noted by Potts (1884) from specimens of *Trochospongilla leidyi* discolored by rust from pipes of waterworks. Potts believed the modification to be due to a chemical condition in the environment.

The other colony, growing about a mass of filamentous algae, unfortunately was very small and flimsy; it contained no gemmules and therefore its identity is unknown. Collections were repeatedly made later, but no other specimens exhibiting these peculiarities could be found. Figures 8 A–F, Plate XXXVI, represent the various conditions among the skeleton spicules. Normal amphioxi with only a bare hint of an axial thread are present but scarce; others may show a wide canal at one end only (A, C); others at both ends (B); in still others — and these are by far the most numerous — it seems that the ends of the spicules are curled back, crispate (D–F). These conditions appear to be the result of an internal decay that reduces the spicule at the ends to a mere shell, which subsequently curls back on itself.

Many of the amphioxi (A–B) show what seems to be a peculiar cap enveloping the extremity. This sheathlike structure surrounding one or both ends is a thick-walled empty cap, overlapping the outer end of the spicule for a short distance, and occasionally the cavity of this structure may be seen extending into the lumen of the spicule. Later, this structure probably splits and breaks (C–D), producing the curled ends (E–F). It is possible that the splitting and curling may have been due to contact with hot HNO_3 in making the spicule slide preparation.

Duncan (1881) has noticed some enlargements of the axial canals in marine sponges and concludes that they are caused by an organism that penetrates and erodes the silica. Both specimens under consideration were infected with filamentous algae, a fact which may be worthy of notice. The waters in which they were found are polluted with industrial wastes. It is probably an environment with a peculiar chemical nature, yet the stream at this point is luxuriant in sponges which seldom show any malformations. Owing to lack of material, further search concerning the probable cause is impossible, and the peculiarity of the spicules is mentioned now only to point out a condition hitherto undescribed.

DISTRIBUTION IN MICHIGAN

(Map 4)

Below are given the locality records for each species found in Michigan till the date of writing this report (February, 1930). Records other than those of the author are shown in parenthesis.

Spongilla aspinosa Potts

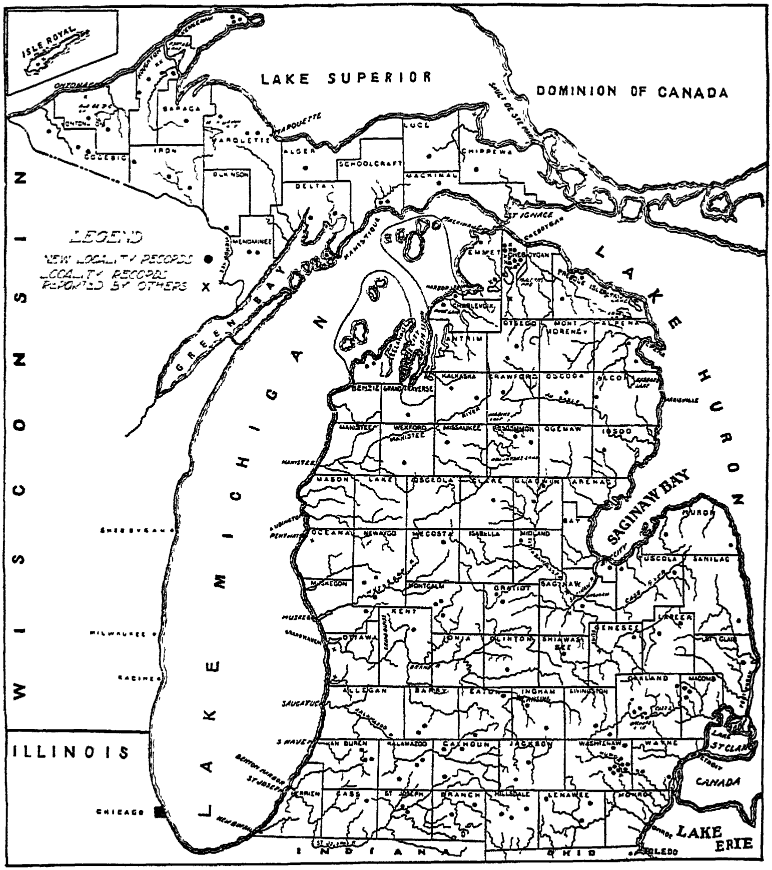
(Map 5)

CHEBOYGAN COUNTY: Malony Lake (Jewell, 1929).

Spongilla lacustris Auctorum

(Map 5)

ALPENA COUNTY: Devil River; BARAGA COUNTY: Ruth Lake; BRANCH COUNTY: Swan Creek; CHARLEVOIX COUNTY: Susan Creek; CHEBOYGAN COUNTY: Bessey Creek, Blanchard Lake, Brown Lake (Jewell, 1929), Maple Bay of Burt Lake, Maple River (Smith, 1915), Mud Lake (Jewell, 1929), Nigger Creek;



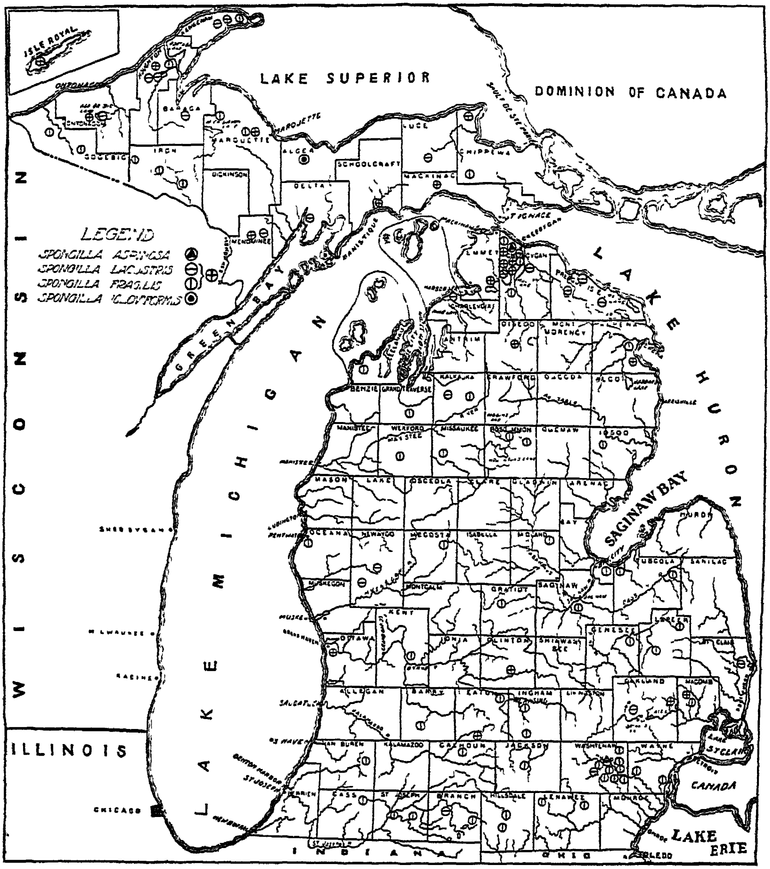
MAP 4. Distribution of new and old locality records

CHIPPEWA COUNTY: Whitefish Point (Hankinson, 1916*a*); CLINTON COUNTY: Lookingglass River; DELTA COUNTY: Days River; EATON COUNTY: Pine Lake; EMMET COUNTY: Crooked River; HOUGHTON COUNTY: South Twin Lake and Stonington Lake (Hankinson, 1916), Beaver Dam Lake; KALKASKA COUNTY: small lake near Kettle Lake; KEWEENAW COUNTY: Lake Fanny Hooe and inlet, lake on Isle Royal (Adams, 1908); LUCE COUNTY: Twin Lakes; MACKINAC COUNTY: lake near Garnet; MACOMB COUNTY: lake near Romeo; MARQUETTE COUNTY: Horseshoe Lake; MENOMINEE COUNTY; lake near Hermansville, Wilson Creek; NEWAYGO COUNTY: Blanch Lake, Brooks Creek; OAKLAND COUNTY: lake near Walled Lake, Clinton River; ONTONAGON COUNTY: Ontonagon River, Merriweather Creek, Carp Creek (Adams, 1908); OSCODA COUNTY: North Helmar Lake; OTSEGO COUNTY: Lake near Gaylord; OTTAWA COUNTY: Grand River (Smith, 1921); PRESQUE ISLE COUNTY: Ocqueoc Creek, Swan River, Twin Lakes; SCHOOLCRAFT COUNTY: Indian River; ST. CLARE COUNTY: Pine River; WASHTENAW COUNTY: Third Sister Lake, Whitmore Lake.

Spongilla fragilis Leidy

(Map 5)

ALPENA COUNTY: Thunder Bay River, Devil River; BARRY COUNTY: Mud Lake; BAY COUNTY: drainage stream; BRANCH COUNTY: stream near Quincy; CALHOUN COUNTY: Garfields Lake; CASS COUNTY: stream in Marcellus Township; CHEBOYGAN COUNTY: Bessey Creek (Smith, 1915), Blanchard Lake, Indian River (Smith, 1915), Maple Bay of Burt Lake (Smith, 1915), Nigger Creek, Sedge Pool (Smith, 1915), Smith's Bog (Smith, 1915, and Jewell, 1929); CHIPPEWA COUNTY: Carp Lake, Whitefish Point (Hankinson, 1916*a*); CLINTON COUNTY: Lookingglass River; EATON COUNTY: Pine Lake, Grand River; EMMET COUNTY: Crooked River; GENESEE COUNTY: Goudy Lake; GLADWIN COUNTY: dry pond, south side of Indian Lake; GOGEBIC COUNTY: Sunday Lake, Tenderfoot River; GRAND TRAVERSE COUNTY: pond near Kingsley;



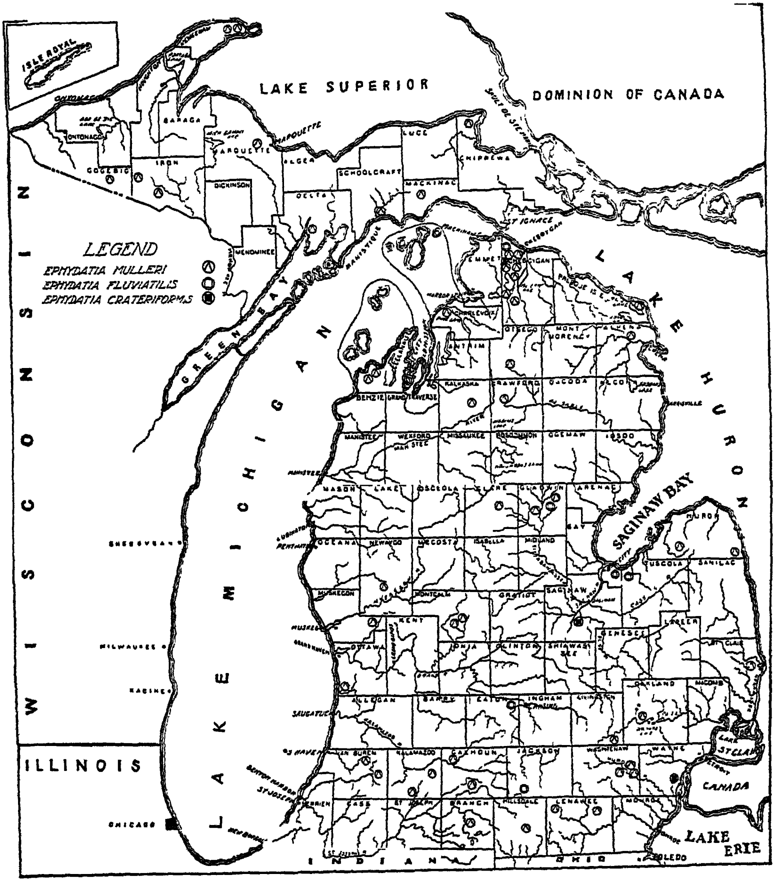
MAP 5. Distribution of records of *Spongilla aspinosa*, *S. lacustris*, *S. fragilis* and *S. igloviformis*

GRATIOT COUNTY: Pine River, pond near Perrinton; HILLSDALE COUNTY: stream in Scipio Township, stream in Hillsdale Township; HOUGHTON COUNTY: Snake River, South Twin Lake (Hankinson, 1916); INGHAM COUNTY: Cedar River, drainage stream from Huntoon Lake; IOSCO COUNTY: Hale Creek; IRON COUNTY: Tamarack River, Iron River, Fortune Lakes; JACKSON COUNTY: stream near Jackson; KALKASKA COUNTY: Black River; KENT COUNTY: Little Egypt Creek; KEWEENAW COUNTY: Fanny Hooe Creek, Lake Fanny Hooe, Chickenbone Lake on Isle Royal; LAPEER COUNTY: pond near North Branch, Flint River; LEELANAU COUNTY: Glen Lake; LENAWEE COUNTY: stream near Cambridge, Raisin River; MACKINAC COUNTY: lake near Garnet; MACOMB COUNTY: stream and lake near Romeo; MARQUETTE COUNTY: Horseshoe Lake, Morgan Creek, creek near Michigamme; MECOSTA COUNTY: Dead Stream; MENOMINEE COUNTY: lake near Hermansville; MISSAUKEE COUNTY: Clam River; OAKLAND COUNTY: Clinton River; OCEANA COUNTY: (Smith, 1921); ONTONAGON COUNTY: Merriweather Creek; OTESGO COUNTY: lake near Gaylord; OTTAWA COUNTY: Grand River (Smith, 1921); ROSCOMMON COUNTY: Au Sable River pond, stream between Higgins Lake and Marl Lake; SAGINAW COUNTY: Cass River; SCHOOLCRAFT COUNTY: Indian River; ST. JOSEPH COUNTY: pond near Centreville, Prairie River; TUSCOLA COUNTY: drainage stream, Cass River; VAN BUREN COUNTY: lake in Almena Township; WASHTENAW COUNTY: four ponds in vicinity of Ann Arbor, pond near Frains Lake, Huron River, (Smith, 1921); WAYNE COUNTY: Huron River, Marsh Creek; WEXFORD COUNTY: pond in Boon Township.

Spongilla igloviformis Potts

(Map 5)

ALGER COUNTY: Ackerman Lake.



Map 6. Distribution of records of *Ephydatia mülleri*, *E. fluviatilis* and *E. crateriformis*

Ephydatia crateriformis (Potts)

(Map 6)

CHEBOYGAN COUNTY: Smith's Bog (Jewell, 1929); SAGINAW COUNTY: Shiawassee River (Smith, 1921, 1921*a*); WAYNE COUNTY: Marsh Creek.

Ephydatia fluviatilis (Auctorum)

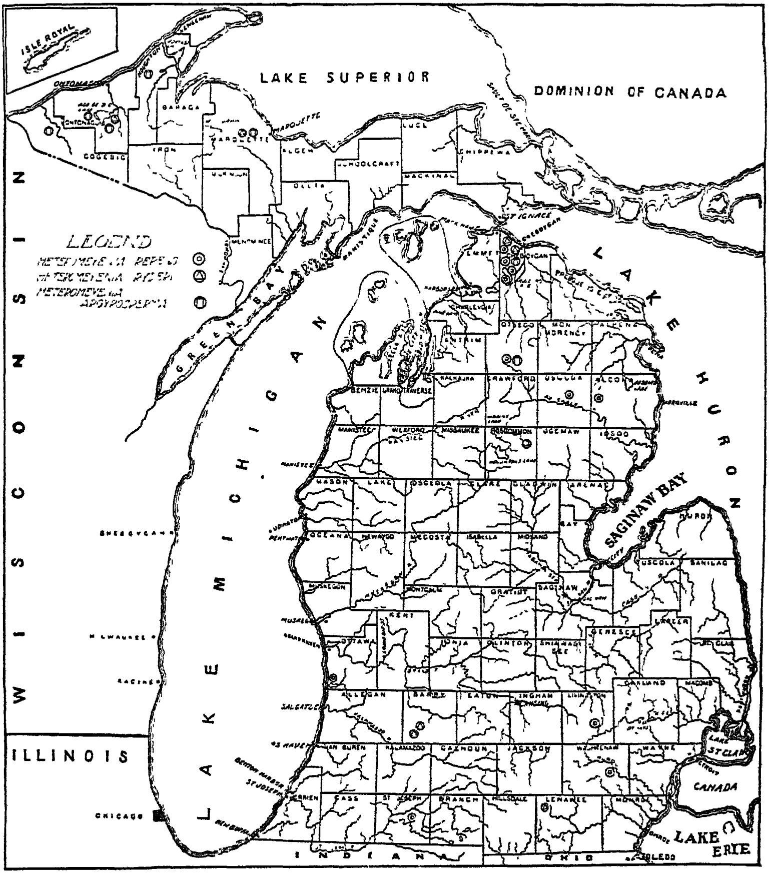
(Map 6)

BAY COUNTY: drainage stream; CHEBOYGAN COUNTY: Bessey Creek (Smith, 1915); EATON COUNTY: Grand River; GLADWIN COUNTY: dry pond near Indian Lake; JACKSON COUNTY: Kalamazoo River; TUSCOLA COUNTY: two separate drainage streams.

Ephydatia mülleri (Lieberkühn)

(Map 6)

ALPENA COUNTY: Thunder Bay River; BRANCH COUNTY: Swan Creek; CALHOUN COUNTY: Nottawaseppe River, Bedford Mill Pond; CHARLEVOIX COUNTY: Adams Creek; CHEBOYGAN COUNTY: Bessey Creek, Blanchard Lake, Burt Lake (Smith, 1915), Crooked River (Smith, 1915), Indian River (Smith, 1915), Maple River (Smith, 1915), Nigger Creek; CHIPPEWA COUNTY: (Hankinson, 1916*a*); CLARE COUNTY: pond near Harrison; CRAWFORD COUNTY: Au Sable River; DELTA COUNTY: Days River; GLADWIN COUNTY: stream near Gladwin, dry pond near Indian Lake; GOGEBIC COUNTY: Morrison Creek; HILLSDALE COUNTY: lake near Osseo; HURON COUNTY: Rock Falls Creek, Pigeon River; IRON COUNTY: Tamarack River, Iron River; KALAMAZOO COUNTY: Portage Creek, Mud Lake Creek; KALKASKA COUNTY: Black Creek; KEWEENAW COUNTY: Fanny Hooe Creek, Lake Fanny Hooe; LEELANAU COUNTY: Glen Lake, Crystal River; LENAWEE COUNTY: stream near Cambridge, Raisin River; LIVINGSTON COUNTY: Nichwaugh Lake; MACKINAC COUNTY: lake near Garnet; MARQUETTE COUNTY: Horseshoe Lake; MONTCALM COUNTY: two streams, one north of Sheridan, the



Map 7. Distribution of records of *Heteromeyenia repens*, *H. ryderi* and *H. argyrosperma*

other northeast of Sheridan; Muskegon County: Crockery Creek; Newaygo County: Robinson Creek; Oakland County: creek near Wolverine Lake; Ottawa County: Black Lake (Smith, 1915); Otsego County; pond on east side of Otsego Lake; Presque Isle County: pond (Smith, 1915); Schoolcraft County: Indian River; St. Clare County: Pine River; Van Buren County: Paw Paw River, Brandywine Creek; Washtenaw County: pond near Ann Arbor, Huron River at Ann Arbor, Third Sister lake.

Heteromeyenia repens Potts

(Map 7)

Alcona County: pond near Crooked Lake; Cheboygan County: East Lake, beach pools (Smith, 1915), Burt Lake (Smith, 1915), Smith's Bog (Smith, 1915); Livingston County: stream near Brighton; Oscoda County: North Helmar Lake; Ottawa County: Black Lake (Smith, 1915); Otsego County: pond on east side of Otsego Lake; St. Joseph County: pond near Centreville; Washtenaw County: Huron River (Smith, 1915).

Heteromeyenia ryderi Potts

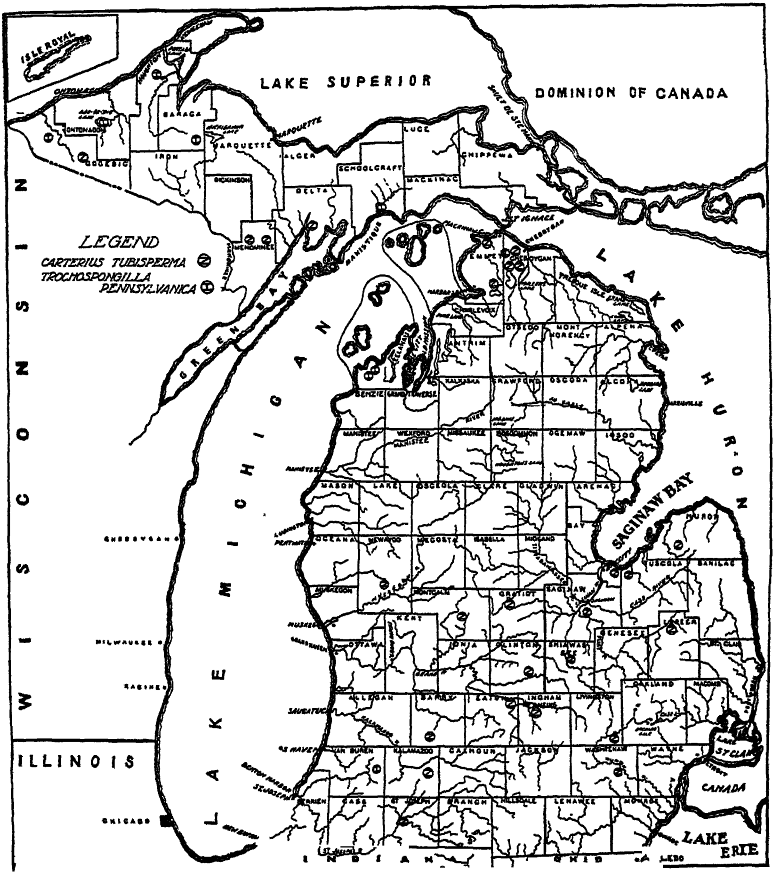
(Map 7)

Barry County: Mud Lake, Crooked Lake; Cheboygan County: Bessey Creek and Smith's Bog (Smith, 1915); Lenawee County: stream near Cambridge; Marquette County: Horseshoe Lake; Ontonagon County: Merriweather Creek; Roscommon County: Au Sable River.

Heteromeyenia argyrosperma Potts

(Map 7)

Cheboygan County: Smith's Bog (Smith, 1915); Gogebic County: Sunday Lake; Houghton County: Beaver Dam Lake; Marquette County: Horseshoe Lake; Ontonagon County: Ontonagon River, Merriweather Creek; Otsego County: pond east of Otsego Lake.



MAP 8. Distribution of records of *Carterius tubisperma* and *Trochospongilla pennsylvanica*

Trochospongilla pennsylvanica (Potts)

(Map 8)

BARAGA COUNTY: Ruth Lake; CHEBOYGAN COUNTY: Smith's Bog (Smith, 1915); GOGEBIC COUNTY: Sunday Lake; HOUGHTON COUNTY: Beaver Dam Lake; LEELANAU COUNTY: Glen Lake, Crystal River; ONTONAGON COUNTY: Merriweather Creek; SCHOOLCRAFT COUNTY: Indian River; VAN BUREN COUNTY: lake in Almena Township.

Carterius tubisperma Mills

(Map 8)

BARRY COUNTY: Crooked Lake; BAY COUNTY: drainage stream; CHEBOYGAN COUNTY: Maple Bay of Burt Lake, Bessey Creek and beach pools (Smith, 1915); CLINTON COUNTY: Lookingglass River; DELTA COUNTY: Days River; EATON COUNTY: Grand River; EMMET COUNTY: Crooked River, French Farm Creek; GOGEBIC COUNTY: Tenderfoot River; GRATIOT COUNTY: Pine River; HURON COUNTY: Pigeon River; INGHAM COUNTY: Cedar River; KALAMAZOO COUNTY: Portage Creek; LAPEER COUNTY: lake near North Branch; LIVINGSTON COUNTY: Nichwaugh Lake; MENOMINEE COUNTY: lake near Hermansville, Wilson Creek; MONTCALM COUNTY: stream northeast of Sheridan; NEWAYGO COUNTY: Robinson Creek; SAGINAW COUNTY: Cass River; SHIAWASSEE COUNTY: Shiawassee River; ST. JOSEPH COUNTY: Prairie River; TUSCOLA COUNTY: drainage stream; WASHTENAW COUNTY: Huron River.

DISCUSSION

Relative abundance of species

Michigan includes within her boundaries representatives of five of the seven genera of fresh-water sponges known for North America. *Spongilla aspinosa, S. lacustris, S. fragilis, S. igloviformis, Trochospongilla pennsylvanica, Ephydatia crateriformis, E. mülleri, E. fluviatilis; Heteromeyenia repens, H. ryderi, H. argyro-*

sperma and *Carterius tubisperma*, or a total of twelve species, are now known to occur in the state. Some are apparently rare; others are quite common. Table I gives a rough estimate of the comparative abundance of each species according to the number of collections made.

TABLE I

COMPARATIVE ABUNDANCE OF SPECIES OF SPONGILLIDAE IN MICHIGAN

Species	No. of collections	Percentage of total	Order of abundance
S. aspinosa	...	....	..
S. lacustris	39	14 3	4
S. fragilis	77	28.2	1
S. igloviformis...	1	0.4	9
T. pennsylvanica	9	3.3	6
E. crateriformis	1	0.4	9
E. mülleri	44	16.0	3
E. fluviatilis	7	2.7	8
H. repens	7	2.7	8
H. ryderi	8	2.9	7
H. argyrosperma	7	2.7	8
C. tubisperma ...	25	9.2	5
Immature forms	47	17.2	2
Total collections	272		

Collections were made from eighty-four streams, forty-two lakes and nineteen ponds. Though the author made every effort to avoid any conscious selection of habitats and examined all possible environments at every opportunity, still these data cannot be interpreted as a final index of the relative abundance of the different species, since it would undoubtedly vary with the kinds of waters examined.

S. lacustris, usually thought of as the most common fresh-water sponge, is outnumbered by *S. fragilis* and *E. mülleri*. *E. fluviatilis*, instead of having a wide distribution, is found to be limited to six counties of the eastern part of the Lower Peninsula. *S. igloviformis* is known only from Ackerman Lake, Alger County. *S. aspinosa* is recorded only from Malony Lake, Cheboygan County. *E. crateriformis* has been found in three widely separated waters: Smith's Bog, Cheboygan County; Shiawassee River, Saginaw County; and Marsh Creek, Wayne County. *H. ryderi* occurs in the western part of the Upper Peninsula and in the northern and southern parts of the Lower Peninsula; *H. repens*, in the southern and northern parts of the Lower Peninsula only; *H. argyrosperma* is limited to the Upper Peninsula and the northern part of the Lower Peninsula. *T. pennsylvanica* appears in the Upper Peninsula, the northern part of the Lower Peninsula, and in the southwestern corner of the state. *C. tubisperma* is more widespread than expected, being missing only from the central part of the Lower Peninsula. *S. lacustris*, *S. fragilis* and *E. mülleri* are apparently the only species now spread over the entire state. Further collections will probably extend the range of at least some of the species mentioned above.

Best collecting grounds

The best collecting grounds for fresh-water sponges in Michigan appear to be in the Upper Peninsula. Not only is the percentage of waters containing sponges greater, but each water is apt to harbor from three to five different species. In most parts of the Lower Peninsula sponge habitats are relatively scarce as compared with the number of waters, and usually not more than two species are found together. Beautiful and luxuriant growths of sponges were found only in certain waters which were completely free from the influences of man. Especially is this true of Horseshoe Lake, between Negaunee and Marquette, in which all possible submerged objects were utilized as a base for at least five different species, which displayed varied and remarkable forms.

Stephens (1920) is of the opinion that sponges in Ireland grow in greatest luxuriance "in a stream or river which drains a lake, and at a point a greater or less distance below the lake." This is evident in Michigan, especially in Bessey Creek, which drains Lancaster Lake into Douglas Lake. Luxuriant growths, however, were also found in streams not draining lakes and in the smaller lakes themselves. The writer is of the opinion that there are too many exceptions to the rule to allow one to generalize concerning the most favorable water. It has not been his experience to find the best specimens in the most rapid currents, notwithstanding the statement of Potts (1887) to the contrary.

Variety of habitats

Potts (1918) cautions sponge collectors not to "waste time in hunting along sluggish streams or in shallow muddy ponds." Morgan (1930) states that "Sponges can live only in clean water." On the other hand, the experience of the past few years convinces the writer that no waters should be overlooked. In fact, many sponges were found in such streams and ponds. Globular colonies, 1–1 1/2 inches in diameter, were occasionally found growing on the mud bottoms of ponds, as well as other forms on submerged wood, vegetation or dead leaves. Highly colored waters also contained many growths of sponges. Specimens of *S. fragilis*, *S. lacustris* and *E. mülleri* were found in abundance attached to copper-bearing rocks in the Keweenaw Peninsula. The color of many of these colonies was a sort of lavender. Hay (1903) discovered a quantity of *S. fragilis* in Echo River within Mammoth Cave, Kentucky.

Other sites which must not be overlooked in making extensive surveys are the dried bottoms of former bodies of water. Late in the summer during this survey the writer came across many dry ponds and streams, or a dry portion of a lake formerly inundated, which yielded numerous specimens. Wood and other solid supports were frequently found bearing abundant dry fragile specimens with many gemmules.

Basins or water courses which have been dry, but which may have accumulated water again even after a few years, must also not be overlooked. Many ponds dry up in the summer season, yet sponges appear again the following spring. According to Weltner (1893), gemmules of *S. lacustris* germinated after being collected from a pond that had been dry for three years; Zykoff raised sponges from gemmules of *E. mülleri* that had been dry for two years; Carter had gemmules germinate after they had been dry from seven to eight years. Weltner tried to raise sponges from gemmules of *T. vesparium* and *S. carteri* that had been dry twenty and thirty years, respectively, but did not succeed. At any rate, it appears that some gemmules may withstand several years' desiccation without injurious effect, and one may expect to find sponges on dry bottoms of former waters and also in bodies of water which have come into existence again after being dry for several years. In South America, on the banks of the Amazon, sponges have been found on the branches of bushes and trees which are submerged only during the rainy season.

Polluted waters

Until this date (1930) it has been supposed that sponges have been eliminated from contaminated waters, although the two following records from the literature hint at a different conclusion. Potts (1887) found sponges occasionally in water "unfit for domestic uses," and Annandale (1911) reports that in India sponges apparently prefer waters unfit for domestic purposes, i.e. polluted by human agencies, and some species are known to occur only in such water. In Michigan sponges have repeatedly been found by the writer growing abundantly in streams receiving sewage from cities. In several such streams the original fauna has been greatly depleted. Waters receiving industrial wastes have also been found with sponge growths, occasionally quite plentiful. Sponges apparently are able to adapt themselves to an environment contaminated with organic or industrial wastes. In spite of the supposed sensitivity to anything abnormal in an environment, the sponges were growing, so far as the writer could observe, in a perfectly normal way.

GEOGRAPHICAL DISTRIBUTION OF MICHIGAN SPECIES

Spongilla aspinosa

Michigan, New Jersey, Virginia. Annandale (1916) describes a specimen from Japan as *S. aspinosa,* but it has spined flesh spicules and consequently should not be confused with Potts' species.

Spongilla lacustris

Alaska.

British Columbia, New Brunswick, James Bay, St. Lawrence River, Ottawa River, Newfoundland, Nova Scotia.

Colorado, Kansas, Illinois, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Montana, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Utah, Washington, Wisconsin, Wyoming.

Austria, Belgium, Bulgaria, Czechoslovakia, Denmark, England, Estonia, Finland, France, Germany, Holland, Hungary, Ireland, Italy, Latvia, Lithuania, Norway, Poland, Portugal, Rumania, Russia, Scotland, Spain, Sweden, Switzerland, Yugoslavia.

China, Japan, India.

Cape Colony, Africa.

Australia, New Zealand.

Spongilla fragilis

British Columbia, Quebec, Newfoundland, Nova Scotia.

Colorado, Florida, Kentucky, Kansas, Illinois, Indiana, Iowa, Maine, Michigan, Minnesota, Montana, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Utah, Wisconsin, Wyoming.

Guatemala.

Brazil.

Belgium, Bulgaria, Czechoslovakia, England, Finland, France, Germany, Ireland, Poland, Rumania, Russia, Scotland, Switzerland, Siberia, China, Japan, India.

Australia.

Spongilla igloviformis

Massachusetts, Michigan, New Jersey, Wisconsin.

Trochospongilla pennsylvanica

Florida, Massachusetts, Michigan, New Hampshire, New Jersey, Ohio, Pennsylvania, Wisconsin.

Newfoundland, Nova Scotia.
Ireland (?), Scotland (?).
India.

Ephydatia crateriformis

Illinois, Indiana, Maryland, Michigan, New York, Ohio, Pennsylvania, Wisconsin.
Mexico.
Ireland (?).
China, India.

Ephydatia mülleri

British Columbia, Newfoundland, Nova Scotia.
Colorado, Illinois, Indiana, Iowa, Maryland, Massachusetts, Michigan, Montana, New Hampshire, New York, Ohio, Pennsylvania, Virginia, Wisconsin.
Austria, Belgium, Bulgaria, Czechoslovakia, England, Finland, France, Germany, Holland, Hungary, Ireland, Poland, Rumania, Russia, Scotland, Sweden, Switzerland, Yugoslavia.
China, Japan.

Ephydatia fluviatilis

British Columbia, Newfoundland, Nova Scotia.
Colorado, Florida, Illinois, Indiana, Michigan, Ohio, Pennsylvania, Wisconsin.
Mexico.
Austria, Belgium, Bulgaria, Czechoslovakia, Denmark, England, Estonia, Finland, France, Germany, Holland, Hungary, Ireland, Italy, Latvia, Norway, Poland, Rumania, Russia, Scotland, Spain, Switzerland, Yugoslavia.
China, India, Japan, Sumatra, Syria, Turkestan.
Australia, New Zealand.
Cape Colony, Africa.

Heteromeyenia repens

Nova Scotia.
Illinois, Indiana, Michigan, New Jersey, New Hampshire, New York, Pennsylvania.
Germany, Poland.

Heteromeyenia ryderi

New Brunswick, Newfoundland, Nova Scotia.
Florida, Georgia, Indiana, Iowa, Maine, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Pennsylvania, Virginia.
Ireland, Scotland.

Heteromeyenia argyrosperma

Newfoundland.
Illinois, Indiana, Michigan, New Hampshire, New Jersey, Pennsylvania, Wisconsin.

Carterius tubisperma

California, Illinois, Indiana, Iowa, Kansas, Massachusetts, Michigan, New York, Ohio, Wisconsin.

DISCUSSION

The geographical distribution of fresh-water sponges is a wide one, although there are still many parts of the world which have not been examined for them. Most of the information concerning distribution comes from casual and scattered collections rather than from extensive examinations of a particular area. The sponge faunas of Europe and India are apparently better known than those of other regions, but even there only limited areas have been examined. All other geographic regions are as yet relatively unknown. So far, only the Malay Peninsula (Dover, 1929) is definitely reported to be entirely devoid of fresh-water sponges.

Some species are apparently cosmopolitan in their range, others, so far as is known, are discontinuous in their range, or limited to one or more land areas. This limitation may be due to a condition suggesting an inability of certain species to become abundant even in waters apparently suitable to them, and consequently the probability of becoming disseminated is low.

Records of the Michigan species of fresh-water sponges and of the major divisions of the world from which they have been reported in various scientific publications are indicated in Table II.

TABLE II

Records of the Occurrence of Michigan Species of Fresh-Water Sponges in Various Parts of the World

	S. aspinosa	S. lacustris	S. fragilis	S. igloviformis	T. pennsylvanica	E. crateriformis	E. mülleri	E. fluviatilis	H. repens	H. ryderi	H. argyrosperma	C. tubisperma
North America	+	+	+	+	+	+	+	+	+	+	+	+
Central America			+									
South America.........			+									
British Isles		+	+		(?)	(?)	+	+		+		
Europe		+	+				+	+	+			
Africa		+						+				
Asia		+	+		+	+	+	+				
Australia		+	+					+				

Questionable locality records

T. pennsylvanica and *E. crateriformis*, originally reported from Ireland by Hanitsch (Stephens, 1920), were reëxamined by Stephens, who decided that both were forms of *H. ryderi*, which is very abundant in Ireland. Specimens of *T. pennsylvanica* and *E. crateriformis* were searched for by Stephens, but never found. Annandale (1909) found *T. pennsylvanica* in Scotland, but reexamination by Stephens showed that it "was undoubtedly the lake form of *H. ryderi*." Consequently, records of these two species from Ireland and one from Scotland should probably be expunged. Pending additional information concerning these forms, the writer has continued to use them under the originally proposed names, but indicates the uncertainty involved in both cases.

SUMMARY

1. The list of sponges of Michigan includes twelve species: *Spongilla aspinosa, S. lacustris, S. fragilis, S. igloviformis, Tro-*

chospongilla pennsylvanica, Ephydatia crateriformis, E. mülleri, E. fluviatilis, Heteromeyenia repens, H. ryderi, H. argyrosperma and *Carterius tubisperma.*

2. Generic and specific identification of sponges by external features is not practicable. Branched colonies among the various species are more common than had been expected, and branched forms as well as unbranched ones of the same species occur in the same environment.

3. Identification of sponges by odor is of little value beyond the possibility of recognizing as sponges those colonies which are disguised by unusual appearance or by extraneous materials.

4. Gemmules are produced by sponges during the favorable season as well as near its close. Sponges with gemmules were found as early as the last week in June and were common by the first week in July.

5. The taxonomic description of each species has been made more nearly complete; it comprises a composite made up as a total of all characters assembled from all specimens collected.

6. All known locality records for the sponges of Michigan have been assembled, including their distribution in the major divisions of the world.

7. The best collecting grounds in Michigan were found in the Upper Peninsula in waters free from the influences of man.

8. Luxuriant growths of sponges are not limited to any particular point in a stream draining a lake or to rapidly flowing streams. Such growths are as likely to occur in standing waters or in flowing waters not connected with lakes.

9. Contrary to statements in the literature, sponges occur in sluggish streams and shallow ponds, where they may grow even on the soft mud bottom; highly colored waters also contain sponges.

10. Sponges may grow in a perfectly normal condition in waters contaminated by industrial and organic wastes.

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EXPLANATION OF PLATES XXXV–XXXVII

(Drawings made with the aid of a camera lucida)

PLATE XXXV

FIG. 1. *Spongilla fragilis.* — *A*, skeleton spicules; *B*, gemmule spicules; *C*, gemmule spicule with axial and subaxial canals

FIG. 2. *S. fragilis.* — *A*, skeleton spicules; *B*, gemmule spicules

FIG. 3. *S. fragilis.* — *A*, skeleton spicules; *B*, gemmule spicules; *C*, abnormal gemmule spicules

FIG. 4. *S. fragilis.* — *A*, skeleton spicules; *B*, gemmule spicules; *C*, abnormal skeleton spicules

PLATE XXXVI

FIG. 5. *Ephydatia mülleri.* — *A*, skeleton spicules; *B*, abnormal gemmule spicules

FIG. 6. *Trochospongilla pennsylvanica.* — *A*, skeleton spicules; *B*, skeleton spicule with axial and subaxial canals; *C*, gemmule spicules; *D*, portion of surface of gemmule showing arrangement of the two kinds of unequal birotulates around the sunken foramen

FIG. 7. *T. pennsylvanica.* — *A*, skeleton spicules; *C*, gemmule spicules

FIG. 8. Sponge unknown. — *A–F*, skeleton spicules; for explanation see page 453.

PLATE XXXVII

FIG. 9. *Heteromeyenia ryderi.* — *A*, skeleton spicules; *B*, gemmule spicules of shorter class; *C*, gemmule spicules of longer class; *D*, end view of *B*

FIG. 10. *H. ryderi.* — *A*, skeleton spicules; *B*, gemmule spicules of shorter class; *C*, gemmule spicules of longer class; *D*, immature gemmule spicule of shorter class

FIG. 11. *H. repens.* — *A*, smooth skeleton spicules; *B*, gemmule spicules of shorter class; *C*, gemmule spicules of longer class; *D*, flesh spicules

FIG. 12. *H. repens.* — *A*, sparsely spined skeleton spicules; *B*, gemmule spicules of shorter class; *C*, gemmule spicules of longer class; *D*, flesh spicule

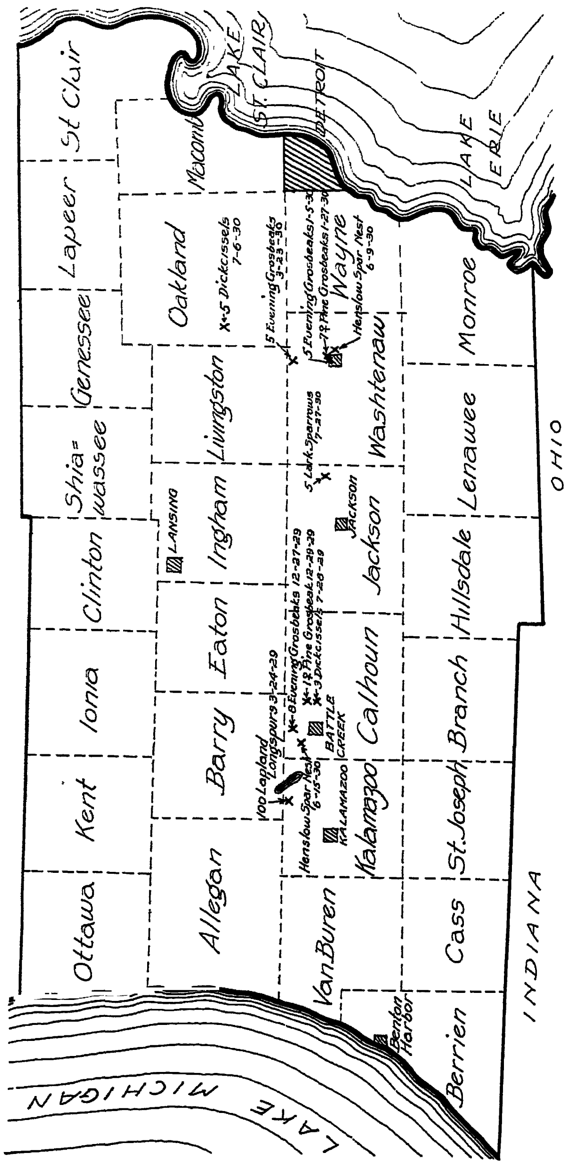
NOTES ON THE OCCURRENCE OF SIX OF THE LESS COMMON SPECIES OF THE FAMILY FRINGILLIDAE, CLASS AVES, IN SOUTHERN MICHIGAN

RICHARD E. OLSEN

THE records here contained were taken from weekly field trips made in the central counties of southern Michigan during the years 1929 and 1930 (see Map 9). Since all the species that are referred to are easily identified there is little chance for error from that source, even though specimens were not collected in three of the six to be considered.

The evening grosbeak (*Hesperiphona vespertina vespertina*) usually does not reach the Michigan-Ohio line during the southward winter movement, but once or twice in a decade a wave of these birds may sweep far to the east and south of their normal range. During the winter of 1929–30 such a migration was recorded. In Calhoun County about five miles north of Battle Creek, on the 27th of December, 1929, eight evening grosbeaks were recognized when they alighted in a solitary tree, rested but a moment, and then continued on their way. In Washtenaw County five evening grosbeaks were seen within the city limits of Ann Arbor on the 5th of January, 1930, and remained until the end of February. The last record of this species was made in Washtenaw County on the 23d of March, 1930, when five of the birds were seen in the fringe of trees on the southern shore of Whitmore Lake. It is of interest that, with the exception of the first group observed, all were in box-elder trees feeding on the seeds.

The pine grosbeak (*Pinicola enucleator leucura*), like the evening grosbeak, does not normally appear in the southern half of the Lower Peninsula of Michigan in winter. During the unusually severe winter of 1929–30 there was a wave of the pine grosbeaks



Map 9. Distribution of less common sparrows

below their customary migration limits. The first specimen was seen in Calhoun County, about five miles north and east of Battle Creek, on the 29th of December, 1929. It appeared to be a female, though its sex cannot be positively stated, since the young male is almost identical in plumage. The bird was perched in a maple tree and was not feeding. It remained for several minutes and then flew to a pine tree about a tenth of a mile distant in the front yard of a farmhouse. The only other record is of a group of at least eleven pine grosbeaks found in a small pine grove near the city limits of Ann Arbor, first seen on the 27th of January, 1930. At no time were more than seven observed, but since ten specimens were collected and one was still present, there must have been a minimum of eleven. The collected specimens proved to be, without exception, females. No pine grosbeaks were found in this location after the second week in February.

The last of the group of three winter visitants to be commented on is the Lapland longspur (*Calcarius lapponicus lapponicus*). But few recent records of this species have been noted in the area under consideration. Only once was this bird observed, and that was on the 24th of March, 1929, in Kalamazoo County. A flock of not less than one hundred was found about three miles to the west of Gull Lake not far from the county line. Since not all the members of the flock could be viewed at one time, it is very probable that several hundred rather than one hundred were present. They were located in an open field which still contained the stubble of the previous year's corn crop. Since they were very adept at hiding behind any slight irregularities in the surface of the ground, it was difficult to observe them. One could walk through the middle of the flock and not see a single bird until the entire group in that part of the field would arise into the air. They were for the most part in an intermediate stage of plumage; some of the males had almost attained the full summer coat, but others resembled the females.

Though the Henslow sparrow (*Passerherbulus henslowi henslowi*) was considered uncommon a few years ago, it was abundant during the summer of 1930. The reason for this rather sudden increase in numbers is not at all clear, and the explanations that have been offered up to the present time have been inadequate. Suffice it to say that in many localities this sparrow was as plentiful as the grasshopper or Savannah sparrows. During the summer two nests of this species were found. The first was in a grassy meadow overlooking the Huron River not far from Ann Arbor. The locality was not marshy, but was a dry upland sloping gently to the river. The nest was seen on the 9th of June and the eggs hatched a few days later. The nest was not quite on the ground, but was placed in the center of an alfalfa plant which gave it a slight elevation. The five eggs were speckled with purple. This was concentrated at the larger end, leaving a clear spot in the middle of the tip. The parent birds were present and scolded whenever the nest was approached. The second nest was found in a swamp northwest of Battle Creek in Calhoun County. There was a stretch of open grassy marsh land with a few ponds of water in the middle. Many short-billed marsh wrens were present and it was to find a nest of that species that the expedition had been made. When the party was crossing the swamp for the last time before returning home, a nest half-concealed by the overhanging grass was found in a hillock; it contained the remains of one egg, two others intact, and a cowbird egg. One of the parent birds had recently been killed by some visitor, since the legs and wings were lying before the entrance of the nest. No clue to the killer could be found. The distribution of the spots on the eggs was the same as in the first ones observed, but the dots were a little larger and more nearly red than purple.

It has been known for some time that the lark sparrow (*Chondestes grammacus grammacus*) may occasionally be found in the hilly counties in the southern part of the state of Michigan. No personal encounters were made with them until at about seven in the morning of the 27th of July, 1930, when two family parties were found in Jackson County about four miles north of Grass Lake. The parent birds were conducting the young ones on personal tours of investigation for food, and though an occasional note was heard there was no singing. An excellent view was obtained of adults and young as they were observed in a ravine at the edge of the field through ten-power field glasses.

The lark sparrows must have raised their broods in the immediate vicinity, and they were present at the same place for the first two weeks of August.

An outstanding mystery of the avian world is the status of the dickcissel (*Spiza americana*). It is very irregular in its appearances throughout its breeding range. One year it will be present, and the next year not an individual will be seen within twenty miles of the spot. It has been suggested that this is a degenerate species on the verge of extinction, but evidence for any substantial loss in numbers is lacking. Two pairs nested in an alfalfa field about five miles northeast of Battle Creek in Calhoun County; after the young birds hatched they were observed about a mile south of the nesting ground on the 28th of July, 1929. In 1930 a group containing at least four singing males and also young birds was found near Milford in the western part of Oakland County. We looked for nests for some time, but could find no remnants and so decided that they had left the nesting grounds and were wandering around the country. They were not present at the same spot a week later. The future actions and status of the dickcissel may well be followed with care to determine if possible what has led to its erratic disposition.

UNIVERSITY OF MICHIGAN

FALL MIGRATION OF THE BLACK DUCK FROM NORTHERN MICHIGAN

MILES D. PIRNIE

THE black duck (*Anas rubripes*) breeds in almost every county in Michigan, and is especially common in the northern half of the state. In late August, when most of the young ducks are "on the wing," this species is conspicuous on many of our marshes and lakes. But shortly after the opening of the hunting season on September 16 the survivors are not so easy to find, and it is commonly assumed that the majority of them have gone south by the first of October. But such guesswork is hardly a satisfactory basis for a waterfowl conservation program, and, accordingly, detailed and accurate studies of duck migrations have been in order.

Numbered leg bands have long been in use for the identification of individual birds and many migration records have been obtained by accidental recovery of the "banded" birds, or by their subsequent capture by hunters, or at other trapping stations. The banding method is especially useful in studying the migrations of those species of ducks which may be lawfully hunted, for between 15 and 30 per cent of all banded ducks are shot and reported by hunters. And this percentage is considered sufficient to indicate the usual dates and routes of migration from each banding station.

Our first comprehensive knowledge of black duck migration was obtained by Mr. H. S. Osler, who has trapped and banded several thousands of these ducks at Lake Scugog in south-central Ontario in the past ten years. To date, more than eight hundred of them have been shot and reported, some from practically every state east of the Mississippi, from New York and Florida to Iowa and Texas, indicating a very wide dispersal from the

Lake Scugog area during the fall and winter months. But the Michigan migration cannot be determined by a study of the Lake Scugog records; and, accordingly, the author is making a study of duck migrations from this state.

In the past three seasons (1928–30) more than one thousand wild black ducks have been banded in Michigan. Of this total, eight hundred and forty-five were banded at the Munuskong State Waterfowl Refuge in northern Michigan, located at a widening of the St. Marys River approximately twenty miles south of Sault Ste. Marie.[1] The traps, which consisted of wire inclosures with funnel entrances baited with grain, were successfully operated from August until late October, though attempts at spring banding were wholly unsuccessful at the Munuskong station. Since all but a few of these ducks were full-winged at the time they were caught, it was impossible to differentiate between migrants and those which had been reared in the local marshes, but since 85 per cent of them were banded before the middle of September, the records of subsequent capture of the banded individuals should give us a fairly accurate notion of the usual fall migration of all black ducks from northern Michigan.

To date we have received reports of the capture of 199, or 24 per cent of the total number of black ducks which was banded at Munuskong. A few records were obtained directly from Michigan hunters, but the majority were relayed through the Biological Survey at Washington, the "clearing house" for such banding records. One hundred and sixty-six (or five sixths of the total) were shot the same season in which they had been banded and at periods of from one day to five months after their latest recorded visit to the banding station; and it is only these records which can properly be used in a study of the fall migration. Of the remaining thirty-three records five have been discarded, owing to incomplete data; twenty-six are of ducks which were shot a year later, and two were of birds that survived two hunting seasons.

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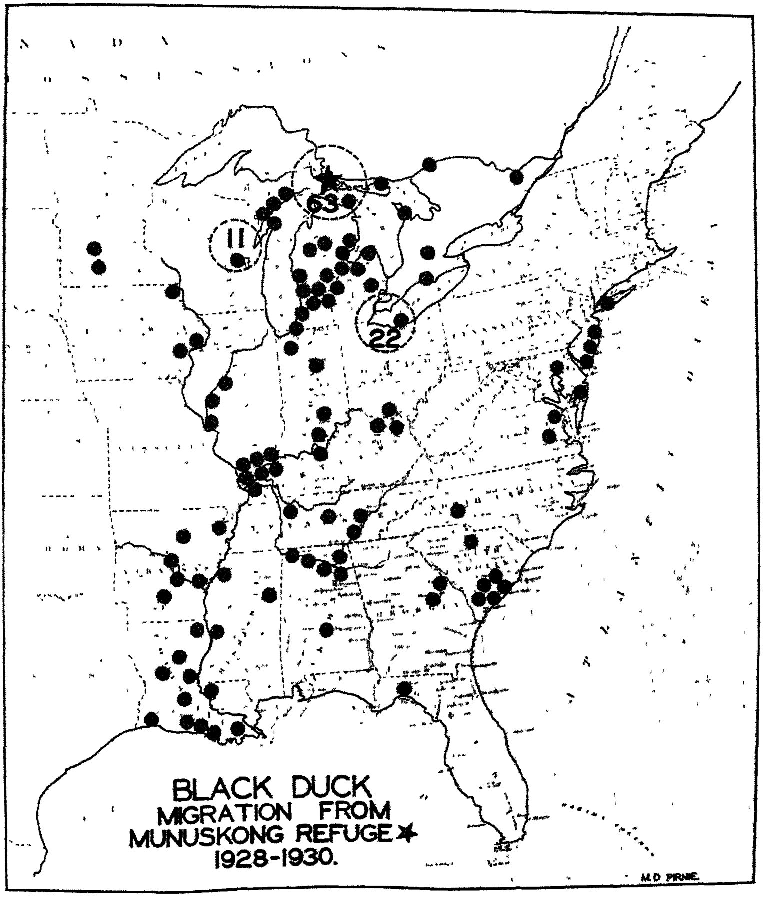
[1] These migration studies were made by the author as part of his work for the Game Division of the Michigan Department of Conservation. Much of the actual "banding" at Munuskong was done by Dr. Karl Christofferson and Floyd Flanders, who were in the Department's service at the Munuskong State Park.



Map 10. Spot map showing locations at which 194 banded black ducks were reported shot. The star indicates the Munuskong Banding Station. The numbers within the three circles denote the total number of banded ducks taken in these areas

The places at which banded ducks have been captured have been located on the spot map (Map 10). A glance at this map shows that larger numbers of the banded ducks were reported from Michigan, Wisconsin, southwestern Ontario, Ohio, Illinois, Arkansas, Louisiana, Alabama and South Carolina. Undoubtedly

TABLE I

SUMMARY OF "RETURN" RECORDS OF BLACK DUCKS

One hundred and sixty-six "return" records were made of black ducks which were shot and reported during the same seasons in which they had been banded at the Munuskong State Waterfowl Refuge (1928–30).

In the table 0 indicates no returns although hunting was permitted; + denotes periods when hunting was prohibited by law.

	Sept.	Oct.	Nov.	Dec.	Jan.	Total
Michigan	44	15	5	1	+	65
Ontario	9	8	2	1	+	20
Wisconsin	5	6	0	1	+	12
Iowa	1	0	1	1	+	3
Minnesota	0	1	0	0	+	1
Ohio	0	2	8	3	+	13
Illinois	+	0	3	5	1	9
Indiana	+	1	1	1	0	3
New Jersey ...	+	0	0	1	1	2
Arkansas	+	+	3	3	0	6
Tennessee	+	+	1	0	2	3
Alabama	+	+	1	1	3	5
Louisiana	+	+	4	3	2	9
Maryland	+	+	0	1	0	1
Kentucky	+	+	0	1	1	2
Virginia	+	+	0	1	1	2
South Carolina	+	+	0	1	3	4
Florida	+	+	0	1	0	1
Mississippi	+	+	0	1	2	3
North Carolina	+	+	0	0	1	1
Georgia	+	+	0	0	1	1
Totals	59	33	29	27	18	166

there was considerable zigzag migration other than the east and west dispersal which is indicated by these records, but we know without question that the majority of these ducks eventually migrated to the southern states.

Comparing these records with those obtained by Mr. Osler,[2] we find that a much larger proportion of the "Munuskong" ducks kept to the interior, and that a far greater number of those banded at Lake Scugog was reported from the Atlantic Coast. This is not surprising, for Lake Scugog lies 300 miles east of Munuskong and only 350 miles from Long Island Sound.

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[2] Lincoln, Frederick C., "Returns from Banded Birds, 1920 to 1923," *U. S. Dept. Agric. Bull. 1268* (1924), 56 p.; "Returns from Banded Birds, 1923 to 1926," *U. S. Dept. Agric., Tech. Bull. 32* (1927), 96 p.

However, most of our data as to the fall migration is obtained by an examination of the return records for the one hundred and sixty-six banded ducks which were shot the same season in which they were banded at Munuskong. These records are tabulated in Table I, which gives the total numbers of banded ducks which were taken each month in each of the twenty-one states or provinces from which they were reported. In the following summary these records are treated as if all the ducks had been banded and shot in a single season, for there are only minor differences between the data obtained in each of the three years.

SUMMARY

1. The majority of the black ducks which are present in northern Michigan in early fall evidently remain in the latitude of Michigan until the latter part of October, for only three of the banded ducks were shot south of Michigan before November. (Duck hunting in Ohio began on September 16, in Illinois on September 24, and in Indiana on October 1.)

2. Of certain groups of ducks trapped in August and early September, some individuals migrated more than 300 miles from Munuskong before the middle of September; others continued to visit the refuge until late October, nearly two months after they had been trapped and banded. This proves that, although certain ducks may associate for a time, they do not necessarily migrate together. It is also evident from these records that refuge areas (even when well baited with wheat and corn) do not entirely prevent migration to other marshes in late summer or early autumn.

3. The southern migration from northern Michigan is evidently well under way by late October and early November, for although hunters north of the Michigan-Ohio line secured eighty-

nine banded ducks by the end of October, they reported getting only ten after November 1. In contrast, hunters in states to the south of Michigan shot sixty-four of the banded ducks after November 1, but only three before that date.

4. During September and October banded ducks were reported from only seven states, but in November and December they were recorded in eighteen states, indicating a wide dispersal by the middle of November. Ducks which were banded together in early fall have been reported in December from Louisiana and New Jersey, separated by a distance of more than one thousand miles.

5. Twelve ducks were reported shot in November at points in the Mississippi Valley between Illinois and Louisiana, but none has been reported from the Atlantic Coast before December. This indicates that the migration into the south-central states takes place earlier than the "drift" to the Atlantic Coast.

6. The capture of several banded black ducks as far north as Illinois, Kentucky and Tennessee as late as December and January shows that not all the northern ducks winter as far south as Louisiana or South Carolina, as is frequently asserted. If duck hunting were permitted in January and February in Michigan, it is not at all unlikely that we would discover some of these ducks wintering in Michigan less than two hundred miles from the Munuskong banding station.

DEPARTMENT OF CONSERVATION
LANSING, MICHIGAN

LIMNOLOGICAL INVESTIGATIONS ON NORTHERN MICHIGAN LAKES

II. A FURTHER STUDY OF DEPRESSION INDIVIDUALITY IN DOUGLAS LAKE *

PAUL S. WELCH AND FRANK E. EGGLETON

IN A previous paper the senior author (Welch, 1927) presented, among other things, data establishing the occurrence of a distinct and diversified individuality in the limnological behavior of six major, isolated, submerged depressions which occur in the main basin of Douglas Lake, Cheboygan County, Michigan. The considerable evidence available at that time showed that each submerged depression acts independently with respect to "(1) date of stratification; (2) position, form, and thickness of the thermocline on a given date; (3) seasonal history of stratification, when established; (4) presence or absence of stratification; and (5) permanency of stratification when established." This independence of action is particularly significant in view of the fact that five of the depressions have maximum depths of 22–28 meters — depths ordinarily ample for the development of thermal stratification and its usual accompaniments in a lake whose position, form and area are similar to those of Douglas Lake. A certain very limited difference in behavior of isolated submerged depressions in the same lake basin might be the natural expectation, since such features as differences in bottom deposits and in exposure to prevailing winds might prevent complete uniformity of action, but the depression individuality which occurs in Douglas Lake far surpasses any such expectation. The extent to which this individuality may go is indicated by such phenomena as the presence in

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* Contribution from the University of Michigan Biological Station and from the Zoölogical Laboratory of the University of Michigan.

one depression of stratification in its usual form and the complete absence of stratification in an adjacent depression whose depth, position and other morphometric characters not only resemble those of the other depression, but also seem to present every reason for expecting ordinary stratification behavior. Other unique forms of individual depression behavior were presented in the paper mentioned above, reference to which should be made for the detailed morphometric and earlier physico-chemical data.

Apparently, the work just mentioned was the first published account of such striking depression individuality. In fact, limnological literature seems to contain virtually nothing on this subject. That lake basins occasionally (frequently, in certain regions) have isolated depressions in the main basin is common knowledge to surveyors, physiographers and others who have occasion to study the physical form of lakes, but limnologists have given little attention to the chemico-physico-biological behavior of comparable depressions in the same lake basin. Thienemann studied such depressions in certain German lakes and presents (1928) comparisons of parallel limnological examinations. The variations which he found were so slight that in his calculations of dissolved oxygen content he stated that it was a matter of indifference which depression was used in determining the necessary vertical physico-chemical data.[1]

Since the publication of the earlier paper (Welch, 1927), results of work covering four additional summers have been secured (1927–30) and form the basis of this report. Vertical series of physico-chemical records were made in each of the six major depressions within Douglas Lake at intervals during June, July and August. These records were made at frequent and regular depth intervals, so that the limits of essential regions were located with satisfactory precision. The methods used were essentially those already described (Welch, 1927). Maps of Douglas Lake showing the position, form and size of the depressions occur in earlier papers (Welch, 1927; Eggleton, 1931) and should be consulted in connection with the following discussion. Circumstances have necessitated changing the name of that depression, formerly known as Camp Davis depression, which occurs in the southeast bay of Douglas Lake (South Fish-Tail Bay) to South Fish-Tail depression.

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[1] After this paper had been written and was in process of publication a paper appeared by S. Yoshimura, "Water Temperature and Dissolved Oxygen in Several Subaqueous Basins of Lake Akimoto, Fukushima," *Archiv für Hydrobiologie*, 23 (1931) : 279–283, in which a certain depression individuality is described as occurring in a lake whose submerged depressions have been produced by volcanic mud flows.

THERMAL CONDITIONS

Examination of Table I reveals definite and consistent lack of agreement in temperature distribution in the different depressions. Thermocline formation, when present, fails to agree, on the same or closely corresponding dates, in any of the depressions save in a very few instances and in these rare exceptions the agreement is wholly temporary, never continuing through the date of the subsequent record. Thermal stratification may be absent, appear, and then disappear, as in Grapevine Point depression, while in a neighboring one (Sedge Point depression), similar in depth, exposure to wind action and profundal area, the performance is quite dissimilar. Lack of agreement in depression performance differs in degree in the six depressions. Certain ones agree in being thermally stratified throughout the summer (South Fish-Tail, Fairy Island and Roberts Point depressions), but beyond this the agreement ceases. Others agree at times in lacking a thermocline, but they differ in other respects. Since the temperature records were made in such a way that the closest depth interval was one meter, accuracy of thermocline demarcation is limited to that extent and it might be argued that in those instances in which the difference in thermocline limits of two depressions is only one meter such difference may be only apparent. Even if it is admitted that such may possibly be the case in some instances, it can scarcely be that all of the one-meter differences are of this sort, but, more important still, most of the differences exceed one meter by substantial margins.

Another point of depression difference appears in bottom temperatures. Four depressions are essentially of equal depth and might be expected to maintain the same bottom temperatures, but such is not the case, since surprising dissimilarity exists. In fact, the relatively small difference in maximum depth of the six major depressions seems to be little concerned in this matter, except, possibly, in Stony Point depression the depth of which is evidently just above that necessary, under existing circumstances, to insure against occasional effects of more violent surface disturbances. Rate of gain in bottom temperature is also an independent phenomenon.

Secondary thermocline formation, not indicated in Table I, appeared occasionally in certain depressions, but none of the records showed agreement in this respect between any two depressions on the same date, even in adjacent depressions.

CHEMICAL CONDITIONS

As might be expected from circumstances described above, chemical conditions likewise reflect depression individuality. In this paper the descriptive term "chemical stratification" is employed to designate that condition in which there occurs, in the vertical series of records, a depth region in which the chemical nature of the water, particularly dissolved oxygen content, undergoes an abrupt quantitative change. Though this term is in rather common use in limnological literature, there seems to be no agreement as to its precise meaning. Chemical stratification, when present, tends to coincide with thermal stratification; this coincidence is most complete in middle and late summer and in those depressions which are continuously thermally stratified from the beginning of the season. In depressions which manifest either irregular or no thermal stratification, summer chemical history tends to become a conflict between the constantly active oxygen-reducing influence of the bottom and the occasional deep-reaching disturbances of surface storms acting upon water whose surface and bottom temperatures differ so little that at least a temporary, more or less complete circulation is possible, with the result that there is the alternate formation of a chemical gradient (sometimes almost to chemical stratification) with a circulation disturbance.

Since bottom materials and their chemical changes determine, to a large extent, the chemical conditions of the superimposed water, it should be noted that the junior author (Eggleton, 1931) has shown, in an extensive study of the profundal bottom fauna of Douglas Lake, that bottom deposits in the various depressions differ in relative amounts of organic matter. It is not altogether clear why such differences should exist in Douglas Lake, but it is not unlikely that they, together with bottom temperature differences, constitute a part, if not all, of the explanation of differences in oxygen-exhaustion rate in the lower waters.

BIOLOGICAL CONDITIONS

In the light of a well-known fact that thermo-chemical stratification usually produces a biological stratification, it would be expected that this depression individuality would also be reflected in the vertical distribution of organisms, particularly the plankton, and such is actually the case. This fact has been demonstrated repeatedly in the various studies on Douglas Lake, but the detailed supporting data need not be brought into this paper. Not only do differences in thermo-chemical stratification bring about differences in biological stratification, but non-stratified depressions present a vertical distribution of organisms of still another sort. A simple but striking confirmation of these facts was always forthcoming at the end of the summer season when floats which had been anchored in various depressions were raised. A vertical rope which extended from the surface float to a heavy anchor at the bottom showed, in stratified depressions, a dense growth of organisms from lake surface to lower limit of the thermocline, at which level this growth suddenly ceased completely and for the remainder of its length the rope was clean. This dividing line occurred at different levels in different depressions; non-stratified depressions showed a *deeper* distribution and a *gradual* reduction of organisms adhering to ropes.

It should also be noted that a depression individuality occurs in quality and quantity of the profundal bottom fauna of various depressions. That certain depressions differ from others in number and kinds of animals which live in the bottom muds was observed several years ago and the facts were confirmed many times in subsequent years. Details of this faunal depression individuality are presented in the work of the junior author (Eggleton, 1931).

DISCUSSION

Causes of depression individuality. — In spite of the fact that depression individuality in Douglas Lake has been studied for some years a satisfactory explanation of underlying causes is still lacking. The behavior of Stony Point depression is almost certainly the result of its shallower depth, its smaller size and its exposed position. Likewise, the unusually well protected position of South Fish-Tail depression must be a principal factor in conditioning its performance. However, it cannot be said positively that other influences may not be present in both these depressions. A truly puzzling situation arises in the other four depressions, all of which occupy exposed positions. An additional depth of about three meters in Fairy Island depression, its larger size and its relative proximity to the west end of the lake might explain some existing differences between this depression and the remaining three, although position alone is not so clearly a possible cause as might be supposed. True it is that prevailing winds are from the northwest, but the center of this depression is four fifths of a mile from nearest land to the west and in the line of prevailing winds it is about a mile from shore. Winds from an easterly direction have a sweep of roughly 2.5–3.0 miles over open water before reaching this depression. It might be granted that size, position and depth of this depression offer some contrast with the remaining three depressions and might well play some part in maintaining its existing individuality.

The case becomes most complicated in the remaining depressions, namely, Grapevine Point, Sedge Point and Roberts Point depressions, which, from the point of view of size, depth and position are strikingly alike and might be expected to behave similarly. Their individuality of behavior far exceeds what might ordinarily be expected; in fact, it is anomalous, since the deepest of the three, Grapevine Point depression, tends to behave as if it were a shallow depression in which circulation extends at times to the bottom. This depression offers the following contrasts with the other two in spite of its slightly greater depth: (1) consistent irregularity of thermo-chemical stratification, with absence of such stratification the more usual condition; (2) markedly higher bottom temperatures; and (3) frequent, striking increases of bottom temperature during summer, as for example, a gain of more than 5 degrees during the summer of 1930. The inconsistency of behavior in Grapevine Point depression argues against certain other explanations, such as the possibility of this depression being a region of either inflow or outflow of subterranean water. That such inflow and outflow do occur somewhere in the Douglas Lake basin is indicated by circumstantial evidence, but the regions of inflow and outflow have not been located.

The winter performance of these depressions is not known. It is possible that some interesting information might be secured at that season since ice cover would eliminate surface disturbance and some measure of the rôle which wind action plays in this depression individuality might possibly be secured.

Sampling procedures. — Depression individuality of the type described in this paper constitutes a double warning to limnologists relating to methods of thermo-chemico-biological sampling, namely: (1) the possible unreliability of records, taken from one depression (or even two) of a multi-depression lake basin, as an index of the whole lake; and (2) the possible inadequacy of one season's results as an index of the expected performance of a lake. These conclusions, presented in the earlier paper (Welch, 1927), are confirmed by additional data contained herein. Knowledge of important details of basin configuration is essential to proper determination of vertical record locations. Also exigencies of seasonal differences must be met by repeated examinations in other years.

SUMMARY

Data from the summer seasons of 1927–30 yield additional confirmation of that depression individuality which exists in midsummer in the six major submerged depressions of Douglas Lake, Michigan. Each of these depressions acts as an independent unit. This individuality is manifested in the thermal, chemical and biological features of the depressions. Established explanations of this individuality are as yet lacking. Form, size, depth and position (degree of protection or exposure) may be influential features in the behavior of certain depressions, but in some depressions it is clear that other conditions, yet unknown, are the causal factors of marked individuality of performance.[2]

UNIVERSITY OF MICHIGAN

[2] A paper by Will Scott, *Investigations of Indiana Lakes. 3. The Lakes of Northeastern Indiana*, Department of Conservation, State of Indiana, 1931, 22 pp., has just appeared. In a lake (James Lake) depression individuality, manifested in temperatures, dissolved gases and plankton, has been found.

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TABLE I

THERMO-CHEMICAL CONDITIONS IN THE DEPRESSIONS OF DOUGLAS LAKE, SUMMERS OF 1927, 1928, 1929 AND 1930

Position of thermocline expressed in meters; temperatures in degrees Centigrade; t.s. = thermal stratification; c.s. = chemical stratification; c.gr. = chemical gradient (gradual change in chemical conditions from surface to bottom); unf. = chemical conditions approximately uniform from surface to bottom; (?) = specification not positive owing to incomplete data

Determination of thermocline limits by use of accepted rule of temperature change of one or more degrees C. per meter of depth. Secondary thermoclines omitted.

SOUTH FISH-TAIL DEPRESSION (Maximum depth, 24 meters)			SEDGE POINT DEPRESSION (Maximum depth, 24 meters)			GRAPEVINE POINT DEPRESSION (Maximum depth, 25 meters)		
Thermocline	Bottom temp.	Chemical conditions	Thermocline	Bottom temp.	Chemical conditions	Thermocline	Bottom temp.	Chemical conditions
	1927			1927			1927	
7/6 = 12–15	11.0	c.s.	7/9 = 14–16	12.9	c.s.	7/8 = 15–16	15.2	c.gr.
7/27 = 12–18	10.9	c.s.	8/5 = 18–20	13.0	c.s.	7/26 = 18–21	15.1	c.s.
8/15 = 16–20	11.0	c.s.	8/15 = 21–22	14.3	c.gr.	8/12 = no t.s.	17.8	c.gr.
	1928			1928			1928	
6/27 = 13–17	9.4	c.s.	6/27 = no t.s.	12.2	c.gr.	6/28 = no t.s.	15.9	c.gr.
7/4 = 13–17	9.9	c.s.	7/7 = no t.s.	14.6	c.gr.	7/1 = no t.s.	16.0	c.gr.
7/21 = 12–17	9.9	c.s.	7/24 = 12–14	15.1	c.s.	7/24 = 12–14	16.5	c.s.
8/14 = 13–18	10.6	c.s.	8/9 = 15–17	14.6	c.s.	8/7 = no t.s.	16 5	c.gr.
			8/14 = 16–17	15.2	c.gr.	8/14 = no t.s.	16.4	c.gr.
	1929			1929			1929	
7/1 = 13–15	8.8	c.s.	6/27 = 17–18	11.0	c.gr.	6/20 = 3–7	12.4	c.gr.
7/3 = 16.0–16.7	8.8	c.s.	7/17 = 14–17	11.2	c.gr.	7/15 = 12–16	12.5	c.s.
7/17 = 12–16	9.1	c.s.	8/13 = 17–20	11.3	c.s.	8/12 = 18–20	13.2	c.s.
8/13 = 15–19	9.4	c.s.						
	1930			1930			1930	
7/7 = 13–16	8.9	c.s.	7/15 = 13–16	13.4	c.s.	7/8 = 13–15	14.2	c.s.
7/31 = 13–17	9.3	c.s.	7/29 = 16–18	13.2	c.s.	7/28 = no t.s.	18 0	c.gr.
8/14 = 14–17	9.5	c.s.	8/16 = 16–18	13.5	c.s.	8/15 = no t.s.	19.5	c.gr.

TABLE I (*Continued*)

THERMO-CHEMICAL CONDITIONS IN THE DEPRESSIONS OF DOUGLAS LAKE, SUMMERS OF 1927, 1928, 1929, AND 1930

Position of thermocline expressed in meters; temperatures in degrees Centigrade; t.s. = thermal stratification; c.s. = chemical stratification; c.gr. = chemical gradient (gradual change in chemical from surface to bottom); unf. = chemical conditions approximately uniform from surface to bottom; (?) = specification not positive owing to incomplete data.

Determination of thermocline limits by use of accepted rule of temperature change of one or more degrees C. per meter of depth. Secondary thermoclines omitted.

STONY POINT DEPRESSION (Maximum depth, 18 meters)			ROBERTS POINT DEPRESSION (Maximum depth, 22 meters)			FAIRY ISLAND DEPRESSION (Maximum depth, 28 meters)		
Thermocline	Bottom temp.	Chemical conditions	Thermocline	Bottom temp.	Chemical conditions	Thermocline	Bottom temp.	Chemical conditions
	1927			1927			1927	
7/9 = no t.s.	16.0	c.gr.	7/5 = 14–16	12.2	c.s.	7/4 = 15–18	12 6	c.s.
7/25 = no t.s.	19.2	c.gr.	7/18 = 14–17	12.5	c.s.	7/16 = 16–18	12 6	c.s.
8/15 = no t.s.	19.0	c.gr.	8/12 = 17–19	13.0	c.s.	8/10 = 20–22	12.8	c.s.
	1928			1928			1928	
6/28 = no t.s.	16.0	c.gr.	6/26 = 17–18	13.6	c.gr.	6/26 = 21–23	9.8	c.s. (?)
7/16 = 12–15	17.4	c.s.	7/12 = 10–11	12.5	c.s.	7/1 = 20–23	10.6	c.s. (?)
7/25 = 13–14	16.4	c.s.	7/25 = 11–14	13.0	c.s.	7/23 = 12–13	11.6	c.s.
8/7 = no t.s.	19.1	c.gr.	8/6 = 13–18	13.0	c.s.	8/6 = 15–17	12.3	c.s.
8/14 = no t.s.	17.8	c.gr.	8/14 = 14–16	13.2	c.s.	8/14 = 14–17	12.5	c.s. (?)
	1929			1929			1929	
6/29 = no t.s.	14.2	c.gr.	6/21 = 3–5	10.2	c.gr.	6/20 = 2–5	10.2	c.gr.
7/16 = 16–17	14.9	c.gr.	6/29 = 10–13	10.4	c.gr.	7/6 = 12–14	10.4	c.gr.
8/12 = no t.s.	18.6	c.gr.	7/16 = 11–15	10.4	c.s.	7/15 = 12–15	10.7	c.s.
			8/10 = 15–18	10.9	c.s.	8/10 = 15–18	11.0	c.s.
	1930			1930			1930	
7/15 = no t.s.	18.0	almost unf.	7/8 = 12–15	12.3	c.s.	7/8 = 13–17	11.8	c.s.
7/29 = no t.s.	19.2	c.gr.	7/25 = 14–16	12 4	c.s.	7/25 = 15–18	12.0	c.s.
8/15 = no t.s.	19.3	c.gr.	8/15 = 15–18	13.4	c.s.	8/14 = 16–18	12.6	c.s.

TABLE II

SUMMARY OF THERMAL STRATIFICATION IN DIFFERENT DEPRESSIONS

Since a similar summary covering the seasons of 1927 and 1928 appears in a paper by the junior author (Eggleton, 1931), this summary will deal only with the seasons of 1929 and 1930.

Temperatures expressed in degrees Centigrade; thickness of epilimnion and hypolimnion and limits of thermocline stated in meters.

Secondary thermoclines omitted.

Records selected from a larger number of available ones.

SOUTH FISH-TAIL DEPRESSION
(Maximum depth, 24 meters)

Date	Temperature		Epilimnion		Thermocline		Hypolimnion	
	Surface	Bottom	Thickness	Fall in temp.	Limits	Fall in temp.	Thickness	Fall in temp.
1929								
July 1	20.6	8.8	13	5.8	13–15	3.4	9	2.6
July 3	18.8	8.8	16	6.4	16–16.7	2.4	7.3	1 2
July 17	24.8	9.1	12	6.6	12–16	7.0	8	2.1
July 31	22.8	9.6	11.3	3.3	12–16	6.7	8	3.2
Aug. 13	21.0	9.4	15	2.1	15–19	8.9	5	0.6
1930								
July 7	21.2	8.9	13	2.8	13–16	7.2	8	2.3
July 31	22.8	9.3	13	3.5	13–17	8.1	7	1.9
Aug. 6	24.2	10.1	12	4.1	12–16	7.8	8	2.1
Aug. 14	20.5	9.5	14	0.5	14–17	8.8	7	1.7

TABLE II (*Continued*)

SEDGE POINT DEPRESSION

(Maximum depth, 24 meters)

Date	Temperature		Epilimnion		Thermocline		Hypolimnion	
	Surface	Bottom	Thickness	Fall in temp.	Limits	Fall in temp.	Thickness	Fall in temp.
1929								
June 27	19.6	11.0	17	6.1	17–18	1.1	6	1.4
July 17	23.6	11.2	14	5.8	14–17	5.0	7	1.6
Aug. 13	20.9	11.6	17	2.2	17–20	6.8	4	0.3
1930								
July 15	19.4	13.4	13	0.4	13–16	4.7	8	0.9
July 29	23.5	13.2	16	4.8	16–18	4.3	6	1.2
Aug. 16	20.7	13.5	16	1.2	16–18	4.5	6	1.5
GRAPEVINE POINT DEPRESSION (Maximum depth, 25 meters)								
1929								
June 20	21.8	12.4	3	0.6	3–7	5.8	18	3.0
July 15	23.9	12.5	12	5.6	12–16	4.6	9	1.2
Aug. 12	21.0	13.2	18	3.2	18–20	3.8	5	0.8
1930								
July 8	21.6	14.5	13	3.0	13–15	3.2	10	1.2
July 28	24.0	18.0			No stratification			
Aug. 15	21.0	19.5			No stratification			

TABLE II (*Continued*)

STONY POINT DEPRESSION

(Maximum depth, 18 meters)

Date	Temperature		Epilimnion		Thermocline		Hypolimnion	
	Surface	Bottom	Thickness	Fall in temp.	Limits	Fall in temp.	Thickness	Fall in temp.
1929								
June 29	18.8	14.2			No stratification			
July 16	23.4	14.9	16	7.1	16–17	1.1	1	0.3
Aug. 12	23.0	18.6			No stratification			
1930								
July 15	19.4	18.0			No stratification			
July 29	23.2	19.2			No stratification			
Aug. 15	21.0	19.3			No stratification			

ROBERTS POINT DEPRESSION

(Maximum depth, 22 meters)

1929								
June 21	20.2	10.2	3	0.2	3–5	3.1	17	6.7
June 29	17.7	10.4	10	0.7	10–13	4.9	9	1.7
July 16	22.4	10.4	11	4.5	11–15	6.4	7	1.1
Aug. 2	22.6	11.2	13	7.0	13–14.4	2.4	7.6	2.0
Aug. 10	22.0	10.9	15	4.0	15–18	6.3	4.0	0.8
1930								
July 8	21.8	12.3	12	2.8	12–15	4.7	7.0	2.0
July 25	23.6	12.4	14	5.4	14–16	3.4	6.0	2.4
Aug. 8	24.5	13.0	11	3.2	11–16	6.1	6.0	2.2
Aug. 15	20.2	13.4	15	0.9	15–18	5.3	4.0	0 8

TABLE II (*Concluded*)

FAIRY ISLAND DEPRESSION

(Maximum depth, 28 meters)

Date	Temperature		Epilimnion		Thermocline		Hypolimnion	
	Surface	Bottom	Thickness	Fall in temp.	Limits	Fall in temp.	Thickness	Fall in temp.
1929								
June 20	25.0	10.2	2	1.6	2–5	7.3	23	5.9
July 6	19.6	10.4	12	2.4	12–14	4.1	14	1.8
July 15	22.6	10.7	12	5.3	12–15	4.4	13	2.2
Aug. 10	21.0	11.0	15	3.1	15–18	5.5	10	1.4
1930								
July 8	20.8	11.8	13	2.8	13–17	4.7	11	1.5
July 25	22.3	12.0	15	4.3	15–18	4.3	10	1.7
Aug. 14	20.5	12.6	16	1.9	16–18	3.8	10	2.2

TABLE III

SUMMARY OF CHEMICAL ANALYSES

Since a similar summary covering the seasons of 1927 and 1928 appears in a paper by the junior author (Eggleton, 1931), this summary will deal only with the seasons of 1929 and 1930.

Abbreviations: t.s., thermal stratification; unf., approximately uniform from surface to bottom; c.s., chemical stratification; c.gr., chemical gradient (gradual quantitative change in chemical features from surface to bottom); (e), estimated (value interpolated from nearest values since no record was available at exact thermocline limits).

Dissolved oxygen expressed in cubic centimeters per liter; free carbon dioxide in parts per million; and methyl-orange alkalinity in parts per million of calcium carbonate. In column for methyl-orange alkalinity, the first number is for surface water and the second is for bottom water. In column for oxygenless zone, limits are expressed in meters, the first number representing upper limit of oxygenless water and second number, bottom; when the numbers are the same, total absence of dissolved oxygen occurred only at bottom level.

For details of corresponding thermal relations, refer to Table II.

SOUTH FISH-TAIL DEPRESSION

Date	Temperature conditions	Chemical conditions	Dissolved oxygen			Free CO_2		Methyl-orange alkalinity	pH	
			Surface and bottom	Thermocline	Oxygenless zone	Surface and bottom	Thermocline		Surface and bottom	Thermocline
1929										
July 1	t.s.	c.gr.	6.42–0.13	4.60–2.93	absent	0.0–5.0	1.5–3.0	120–126	8.3–7.0	7.7–7.3
July 3	t.s.	c.s.	6.14–0.06	2.26(e)–1.38(e)	absent	0.0–6.0	3.0(e)–3.5(e)	120–128	8.3–7.0	7.3(e)–7.2(e)
July 17	t.s.	c.s.	6.0–0.0	4.74–1.32	21–24	0.0–6.0	1.5–5.0	123–123(e)	8.3–7.0	7.8–7.1
July 31	t.s.	c.s.	6.14–0.0	3.42–1.25	18–24	0.0–5.0	1.0–2.0	120–126	8.3–7.0	7.8–7.3
Aug. 13	t.s.	c.s.	6.14–0.0	4.86–0.19	20–24	0.0–6.0	1.0–4.0	120–126	8.3–7.0	7.8–7.1
1930										
July 9	t.s.	c.s.	6.35–0.06	4.67–0.89	absent	0.0–11.0	0.5–3.5	126–137	8.2–7.0	7.9–7.2
July 31	t.s.	c.s.	5.72–0.0	4.32–0.0	17–24	0.0–10.0	0.0–5.0	126–131	8.2–6.9	8.0–7.0
Aug. 6	t.s.	c.s.	5.65–0.0	2.23–0.48	19–24	0.0–15.0	2.0–4.0	126–133	8.2–6.8	7.5–7.2
Aug. 14	t.s.	c.s.	5.58–0.0	5.09–0.0	17–24	0.0–15.0	0.0–10.0	126–136	8.2–6.8	8.1–6.9

TABLE III (*Continued*)

SEDGE POINT DEPRESSION

Date	Temperature conditions	Chemical conditions	Dissolved Oxygen			Free CO_2		Methyl-orange alkalinity	pH	
			Surface and bottom	Thermocline	Oxygenless zone	Surface and bottom	Thermocline		Surface and bottom	Thermocline
1929										
June 27	t.s.	c.gr.	5.8–0.35	2.22(e)–1.83(e)	absent	0.0–5.0	3.1(e)–3.4(e)	123–128	8.3–7.1	7.4(e)–7.3(e)
July 17	t.s.	c.gr.	6.0–0.0	2.79(e)–0.06	20–24	0.0–5.0	3.0(e)–4.0	121–125	8.3–7.1	7.4(e)–7.1
Aug. 13	t.s.	c.s.	6.14–0.0	3.96–0.32	24–24	0.0–5.0	3.0–4.0	120–127	8.3–7.0	7.6–7.2
1930										
July 15	t.s.	c.s.	6.18–0.01	5.28–0.34	absent	0.0–5.0	0.0–4.0	120–129	8.2–7.0	8.0–7.1
July 29	t.s.	c.s.	5.72–0.0	7.4–7.1	22–24	0.0–11.0	4.0–8.0	123–133	8.2–7.1	7.4–7.1
Aug. 16	t.s.	c.s.	5.79–0.0	4.6–0.76	20–24	0.0–10.0	0.0–6.0	124–133	8.2–7.0	8.0–7.1

GRAPEVINE POINT DEPRESSION

Date	Temperature conditions	Chemical conditions	Dissolved Oxygen			Free CO_2		Methyl-orange alkalinity	pH	
			Surface and bottom	Thermocline	Oxygenless zone	Surface and bottom	Thermocline		Surface and bottom	Thermocline
1929										
June 20	t.s.	c.gr.	5.34–2.74	5.06–5.27	absent	0.0–2.5	0.0–0.5	....	8.3–7.4	8.2–7.8
July 15	t.s.	c.s.	6.07–0.27	3.83–1.88(e)	absent	0.0–5.0	0.5–2.6(e)	120–126	8.3–7.1	7.7–7.3(e)
Aug. 12	t.s.	c.s.	6.08–0.0	3.71–0.0	20–25	0.0–5 0	2.0–4.5	120–124	8.3–7.1	7.6–7.2
1930										
July 8	t.s.	c.s.	5.79–0.13	3.97–1.53	absent	0.0–5.0	1.0–4.0	126–134	8.2–7.1	7.9–7.2
July 28	t.gr.	c.gr.	5.51–1.18	....	absent	0.0–5.0	....	122–131	8.2–7.3	....
Aug. 15	t.gr.	c.gr.	5.86–3.49	....	absent	0.0–2.0	....	126–130	8.2–7.8	....

TABLE III (*Continued*)

STONY POINT DEPRESSION

Date	Temperature conditions	Chemical conditions	Dissolved oxygen			Free CO_2		Methyl-orange alkalinity	pH	
			Surface and bottom	Thermocline	Oxygenless zone	Surface and bottom	Thermocline		Surface and bottom	Thermocline
1929										
June 29	t.gr.	c.gr.	5.79–2.23	....	absent	0.0–2.5	....	120–123	8.2–7.3	....
July 16	t.s.	c.gr.	6.0–0.0	....	18–18	0.0–4.0	....	121–124	8.3–7.2	....
Aug. 12	t.gr.	c.gr.	6.01–3.71	....	absent	0.0–2.0	....	120–124	8.3–7.7	....
1930										
July 15	t.gr.	almost unf.	5.97–5.76	....	absent	0.0–0.0	....	121–130	8.2–8.1	....
July 29	t.gr.	c.gr.	5.72–1.74	....	absent	0.0–4.0	....	123–132	8.2–7.3	....
Aug. 15	t.gr.	c.gr.	5.93–4.88	....	absent	0.0–0.0	....	126–130	8.2–8.0	....
ROBERTS POINT DEPRESSION										
1929										
June 21	t.s.	c.gr.	6.44–0.96	6.08(e)–5.48	absent	0.0–9.6	0.0–1.0	120–122	8.3–7.2	8.3–7.7
June 29	t.s.	c.gr.	5.65–1.18	5.51–3.83	absent	0.0–5.0	0.0–2.0	121–125	8.2–7.1	8.0–7.4
July 16	t.s.	c.s.	5.93–0.0	4.33–1.26	18–22	0.0–5.0	2.0–3.0	121–125	8.3–7.0	7.7–7.3
Aug. 2	t.s.	c.s.	6.14–0.0	2.12(e)–1.20(e)	18(e)–22	0.0–5.0	2.0(e)–3.0(e)	120–126	8.3–7.0	7.4(e)–7.2(e)
Aug. 10	t.s.	c.s.	6.14–0.0	5.05–0.25	20–22	0.0–5.0	1.0–4.0	120–126	8.3–7.0	7.8–7.1
1930										
July 8	t.s.	c.s.	5.86–0.0	4.74–1.95	19(e)–22	0.0–7.0	1.0–5.0	126–134	8.2–7.0	7.8–7.2
July 25	t.s.	c.s.	5.65–0.06	4.74–1.39	absent	0.0–10.0	0.0–4.5	125–135	8.2–7.1	7.9–7.5
Aug. 8	t.s.	c.s.	5.86–0.0	3.59(e)–0.01	17–22	0.0–10.0	2.0(e)–7.0	126–134	8.2–7.0	7.7(e)–7.1
Aug. 15	t.s.	c.s.	5.72–0.0	5.44–0.27	19(e)–22	0.0–10.0	0.0–5.0	126–133	8.2–7.0	8.0–7.1

TABLE III (*Concluded*)

FAIRY ISLAND DEPRESSION

Date	Temperature conditions	Chemical conditions	Dissolved Oxygen			Free CO_2		Methyl-orange alkalinity	pH	
			Surface and bottom	Thermocline	Oxygenless zone	Surface and bottom	Thermocline		Surface and bottom	Thermocline
1929										
June 20	t.s.	c.gr.	5.34–1.43	5.27–5.27	absent	0.0–5.0	0.0–1.0	....	8.3–7.3	8.2–7.9
July 6	t.s.	c.gr.	6.07–0.48	4.46–4.15(e)	absent	0.0–4.0	2.0–3.0(e)	120–127	8.3–7.1	7.6–7.5(e)
July 15	t.s.	c.gr.	6.14–0.06	4.18–2.23	absent	0.0–5.0	1.5–3.0	121–128	8.3–7.1	7.6–7.3
Aug. 10	t.s.	c.s.	6.14–0.0	4.86–1.28	20–28	0.0–5.0	2.0–4.0	120–125	8.3–7.0	7.7–7.1
1930										
July 8	t.s.	c.s.	5.72–0.2	5.23–0.83	absent	0 0–8.0	0.0–6.0	125–136	8.2–7.0	8.0–7.0
July 25	t.s.	c.s.	5.93–0.0	3.97–1.11	22–28	0.0–12.0	1.5–6.5	124–139	8.2–7.0	7.7–7.3
Aug. 14	t.s.	c.s.	5.86–0.0	4.88–0.83	23–28	0.0–11.0	1.0–5.0	130–130	8.2–7.0	7.8–7.1

INDEX OF AUTHORS AND SUBJECTS

PAGE

Ackley, Alma B. Preliminary Report on Michigan Algae, exclusive of Desmids and Diatoms 1

Ackley, Alma B., and Nichols, George E. The Desmids of Michigan, with Particular Reference to the Douglas Lake Region 113

Allen, Shirley W. Nomenclature in the Literature of Forest Fire Control 183

Arnold, Chester A. Microfossils from Greenland Coal 51

Baxter, Dow V. Some Resupinate Polypores from the Region of the Great Lakes. III 191

Chickering, Arthur M. Notes and Studies on Arachnida. II. Araneae from the Douglas Lake Region, Michigan. I 349

Chickering, Arthur M. Spermatogenesis in the Belostomatidae. III. The Chromosomes in the Male Germ Cells of a Lethocerus from New Orleans, Louisiana 357

Chromosome Configurations during the Heterotypic Prophase and Metaphase in Certain Oenotherae and Their Genetic Significance. Chandrakant G. Kulkarni 83

Cochran, Lloyd C. A Thermophilic Calothrix in Michigan 63

Comparative Morphology of Germinating Ascospores in Certain Species of the Hysteriaceae (The). Marion L. Lohman 97

Desmids of Michigan, with Particular Reference to the Douglas Lake Region (The). George E. Nichols and Alma B. Ackley 113

Distribution of the Genus Potamogeton in Michigan. Henry J. Oosting 141

Eggleton, Frank E. Limnetic Distribution and Migration of Corethra Larvae in Two Michigan Lakes 361

Eggleton, Frank E., and Welch, Paul S. Limnological Investigations on Northern Michigan Lakes. II. A Further Study of Depression Individuality in Douglas Lake 491

Experimental Verification of Natural Hybridization between Distinct Genera of Sunfishes. Carl L. and Laura C. Hubbs 427

Fall Migration of the Black Duck from Northern Michigan. Miles D. Pirnie 485

Fur Bearers in Michigan's Forest Areas. Harry D. Ruhl 261

Gilmore, Melvin R. Plant Vagrants in America 65

PAGE

Gloyd, Howard K. The Herpetological Fauna of the Pigeon Lake Region, Miami County, Kansas.......... 389

Hankinson, Thomas L. Observations on the Breeding Behavior and Habitats of Fishes in Southern Michigan.......... 411

Herpetological Fauna of the Pigeon Lake Region, Miami County, Kansas (The). Howard K. Gloyd.......... 389

Hubbs, Carl L. and Laura C. Experimental Verification of Natural Hybridization between Distinct Genera of Sunfishes.......... 427

Janaki-Ammal, Edavaleth K. A Polyploid Eggplant, *Solanum melogena* L.......... 81

Kittredge, Joseph Jr., and Olson, George T. Sampling Forest Types: Suggestions Based on the Michigan Land Economic Survey 229

Kulkarni, Chandrakant G. Chromosome Configurations during the Heterotypic Prophase and Metaphase in Certain Oenotherae and Their Genetic Significance.......... 83

Limnetic Distribution and Migration of Corethra Larvae in Two Michigan Lakes. Frank E. Eggleton.......... 361

Limnological Investigations on Northern Michigan Lakes. II. A Further Study of Depression Individuality in Douglas Lake. Paul S. Welch and Frank E. Eggleton.......... 491

Lohman, Marion L. The Comparative Morphology of Germinating Ascospores in Certain Species of the Hysteriaceae.......... 97

McIntire, George S. Theory and Practice of Forest Typing, with Special Relation to the Hardwood and Hemlock Associations of Northern Michigan.......... 239

Matthews, Donald M. A Short Method of Estimating Possibilities of Sustained Yield in Forest Production.......... 253

Microfossils from Greenland Coal. Chester A. Arnold.......... 51

Nichols, George E., and Ackley, Alma B. The Desmids of Michigan, with Particular Reference to the Douglas Lake Region.......... 113

Nomenclature in the Literature of Forest Fire Control. Shirley W. Allen.......... 183

Notes and Studies on Arachnida. II. Araneae from the Douglas Lake Region, Michigan. I. Arthur M. Chickering.......... 349

Notes on the Occurrence of Six of the Less Common Species of the Family Fringillidae, Class Aves, in Southern Michigan. Richard E. Olsen.......... 479

Observations on the Breeding Behavior and Habitats of Fishes in Southern Michigan. Thomas L. Hankinson.......... 411

Old, Marcus C. Taxonomy and Distribution of the Fresh-Water Sponges (Spongillidae) of Michigan.......... 439

Olsen, Richard E. Notes on the Occurrence of Six of the Less Common Species of the Family Fringillidae, Class Aves, in Southern Michigan.......... 479

PAGE
OLSON, GEORGE T., AND KITTREDGE, JOSEPH JR. Sampling Forest Types: Suggestions Based on the Michigan Land Economic Survey 229
OOSTING, HENRY J. Distribution of the Genus Potamogeton in Michigan 141
Penetrating Power of the Rhizome of Quack Grass *Agropyron repens* (L.) Beauv. (The). EDWARD F. WOODCOCK........................ 179
PIRNIE, MILES D. Fall Migration of the Black Duck from Northern Michigan.. 485
Plant Vagrants in America. MELVIN R. GILMORE.................. 65
Polyploid Eggplant, *Solanum melogena* L. (A). EDAVALETH K. JANAKI-AMMAL.. 81
Preliminary Report on Michigan Algae, exclusive of Desmids and Diatoms. ALMA B. ACKLEY.............................. 1
Results of Thinning in White Pine. LEIGH J. YOUNG................ 337
RUHL, HARRY D. Fur Bearers in Michigan's Forest Areas........... 261
Sampling Forest Types: Suggestions Based on the Michigan Land Economic Survey. JOSEPH KITTREDGE, JR., AND GEORGE T. OLSON 229
Seed Development in *Amaranthus caudatus* L. EDWARD F. WOODCOCK 173
Short Method of Estimating Possibilities of Sustained Yield in Forest Production (A). DONALD M. MATTHEWS...................... 253
Soil Maps as a Basis for Mapping Original Forest Cover. JETHRO OTTO VEATCH.. 267
Some Resupinate Polypores from the Region of the Great Lakes. III. DOW V. BAXTER.. 191
Spermatogenesis in the Belostomatidae. III. The Chromosomes in the Male Germ Cells of a Lethocerus from New Orleans, Louisiana. ARTHUR M. CHICKERING...................................... 357
Stem Form of White Oak. ROBERT KIRBY WINTERS................ 275
Taxonomy and Distribution of the Fresh-Water Sponges (Spongillidae) of Michigan. MARCUS C. OLD.............................. 439
Theory and Practice of Forest Typing, with Special Relation to the Hardwood and Hemlock Associations of Northern Michigan. GEORGE S. McINTIRE.. 239
Thermophilic Calothrix in Michigan (A). LLOYD C. COCHRAN........ 63
VEATCH, JETHRO OTTO. Soil Maps as a Basis for Mapping Original Forest Cover.. 267
WELCH, PAUL S., AND EGGLETON, FRANK E. Limnological Investigations on Northern Michigan Lakes. II. A Further Study of Depression Individuality in Douglas Lake........................ 491
WINTERS, ROBERT KIRBY. Stem Form of White Oak............... 275
WOODCOCK, EDWARD F. The Penetrating Power of the Rhizome of Quack Grass *Agropyron repens* (L.) Beauv...................... 179
WOODCOCK, EDWARD F. Seed Development in *Amaranthus caudatus* L. 173
YOUNG, LEIGH J. Results of Thinning in White Pine............... 337

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